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Maida Morris

A NEW THEORY,

ACCOUNTING FOR THE

DIP OF THE MAGNETIC NEEDLE,

BEING

AN ANALYSIS OF

TERRESTRIAL MAGNETISM,

WITH A SOLUTION OF THE LINES OF

VARIATION AND NO VARIATION,

AND

AN EXPLANATION OF THE

NATURE OF A MAGNET.

BY JAMES BARLOW.

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PREFACE.

Of all the instruments which man has made subservient to his wants, none is so extensively useful as the Mariner's Compass; for, next to the plough and the spade, it may be said to be the main prop of civilized life. Without commerce, we could sow and we could reap, and thus support existence; but we should be reduced to a solitary state, dependent on our own exertions, and deprived of the comforts of life, for want of a market to dispose of our surplus produce: for our neighbors would raise the same fruits as ourselves, by reason of the similarity of climate. In such a state of society, however, we should derive but little benefit from the mechanic arts: those only would be of use which served to clothe and shelter us from the inclemency of the weather. That grand conception, the steam engine—that miracle of human enterprise, capable of abridging the work of thousands without leaving an idle hand in the community—could it be contrived and completed in this state of society, by some master-spirit, whose genius might triumph over the fetters and restraints of solitude, would be utterly useless; for its unbounded powers of production would lie idle on the inventor's hands; a home market would never repay his ingenuity.

The Supreme Architect, however, has not ordained an uniformity of climate from pole to pole; and though he has made man so wonderfully that he can accommodate himself to the circumstances of an equatorial or arctic climate; to the fervid reflection of the scorching sands of Africa, glowing with the intensity of a vertical sun; or to the hyperborean rigors of those dreary and desolate regions, whose iron womb and snow-clad bosom, deny him all the loveliness of nature's livery—so dreary and monotonous that even the fertilizing sun forgets to look upon his patrimony for months together; though man is so wonderfully formed, that he can accommodate himself to all this, yet cannot, for the most part, the rest of nature's works.

Every zone has its peculiar attributes, both in the animal and vegetable kingdoms, confined chiefly to its own sphere. It is true, that many tropic animals and plants are to be found without the limits of the torrid zone, and also, that many whose natural habits betoken a polar constitution are to be found beyond the circles; but the ability of existing far from the latitude of the zone or climate of their origin is generally circumscribed. The tropic elephant, and the polar bear, if transported from their respective zones, to the latitude of 45°, would equally perish; the one of cold, and the other of heat: the sugar cane and the nutmeg of the tropics, and many polar mosses and cryptogamous plants, would wither, if transplanted to the same latitudes. Some few plants and animals are found every where, and the most useful are capable of being extensively acclimated, when subjected to the fostering care of man.

The image of his Maker, and lord of all, man alone is naturally of a constitution to endure all changes; and this adaptation is most strikingly exhibited in those races, who, like ourselves, inhabit the middle regions of the temperate zone. Subject to the alternate extremes of heat and cold, and by choice subsisting on the fruits of an ungrateful soil, which will abundantly repay our industry, but leave us to starve if we are idle, we are compelled to exert those energies with which we are endowed.

In the tropical regions, where nature is profuse and lavish of her gifts, and where the teeming soil offers him spontaneously every luxury that animal and vegetable existence can supply, man leads a life of comparative laziness. In the polar circles, a frost-bound soil, and stinted vegetation leave him but few resources, and limit his natural thirst for acquisition to obtaining his own immediate wants: and, though by industry he may accumulate more than is necessary, yet he has no means of disposing of his surplus wealth. In the middle regions, on the contrary, the real wants of society, owing to the changeableness of climate, and the artificial wants, arising from the different grades of society, cause a wish for a share of the luxuries of his northern and southern neighbors.

He must season his food with the nutmeg, and the clove, and the concrete juice of the sugar cane; for his palate is as sensible, and his taste as exquisite, as that of him who is born beneath the rays of a vertical sun, and who inherits these luxuries as his birth-right. His native oak looks homely in his eyes, and rosewood and mahogany must supply its place. He is not even content with the apple and the plum, and such fruits as are natural to his native clime. No! he must banquet on the pine-apple and the orange, or his meal is incomplete. The fleecy covering of the sheep is superseded by the thread of the silkworm, in the dresses of the fair; ivory must be procured for their fans, and tortoise-shell for their combs. The bowels of the earth must be ransacked for the hidden diamond, the amethyst, and the ruby; and old ocean himself must submit to have his caves explored and plundered of his treasured pearls. Nor must the frozen regions of the north be left unsearched; the ermine and the beaver must pay the forfeit of their lives to supply us with furs for luxurious winter clothing: the procuring and manufacture of which articles furnish food for millions.

But all these things, are not to be obtained for nothing: an equivalent must be given for them to their possessor. The raw produce of his temperate climate will not, however, generally purchase the costly luxuries of the south: this gives an incentive to the native ingenuity of man; and a remedy is found in the arts and manufactures. For this, the artist constructs the steam-engine, doomed thenceforth to ply its leviathan energies night and day, and to minister unceasingly to the increasing demands of its owner. The varied and unbounded results of this enormous power would still remain confined to the spot of its creation, were it not for the facility of transport afforded by the oceans and other waters of the globe.

To render these natural advantages subservient to his purposes, the proud and gallant ship, freighted with the manufactures of the middle latitudes, leaves her port and furrows the depths of ocean. The land of his nativity recedes from the view of the hardy mariner, his home, his friends; the howling winds rush tempestuously by; the dashing billows yield but a momentary and fitful glance at the unsteady horizon; and not a friendly star, in the gloom of night, looks down upon him, like a pitying eye from heaven to guide and illumine his course. But let the winds howl! and let heaven's hundred eyes be closed upon the bark! she shall not perish—she shall not wander far from her destined track; for she has a constant and a faithful friend, that heeds not the blackness of the gathering storm, or the palpable obscure of an approaching night.

The faithful loadstone—the guardian angel of the vessel—the tutelary spirit of navigation—speaks in a language silent, but intelligible; in a tongue whose eloqence is understood by all. The Mariner's Compass may indeed be emphatically called "the sign-post of the deep."

When first man ventured on the fickle element, his voyages were confined to the coasts: it were madness to lose sight of the shore; for his only guides were the heavenly bodies; and as these are liable to be suddenly obscured, when this was the case, he had no known point to steer for. The discovery of the polarity of the magnet, however, and the practical application of this remarkable property, forming the instrument called the Compass, the very soul of navigation, has wrought an era in the history of man of unparalleled importance. Instead of confining our commerce to our own immediate neighbors, and leaving them to do the same with theirs, thus slowly spreading the products of our ingenuity and labor over the world, and enormously enhancing their value, by causing them to pass through a multitude of hands; we can now venture across the boundless ocean, and a few short months join the middle latitudes to every part of the habitable world. Such is the consequence of the triumph man has achieved over an apparent impossibility, viz. the means of distinguishing the four cardinal points of the heavens in the pitchy darkness of a stormy night. What the concentrated wisdom of the world could not divine at such a time, a senseless blade of steel will unerringly detect.

And this should teach us, however we may doubt the pretensions of a discoverer, never to ridicule him, as is but too frequently the case with the world; at least, till his project has received a fair trial. Suppose the Compass were yet unknown; and, as the benefactor of mankind, the author of this work should stand forth and proclaim to the world that he could construct an instrument which should guide a vessel safely out of sight of land, by indicating the north, though you should turn it ever so frequently the other way: would not the apparently physical impossibility of the thing give rise to an unanimous exclamation of "He is a schemer, an impostor, one who wishes to enrich himself by the gullibility of the public?" Yet, by the magnetic needle, he proves the truth of his assertion, however mysterious and inexplicable its nature may appear. What, then, becomes of the ridicule which was heaped upon him?

Like many other inventions which have essentially contributed to the advancement of the moral and physical condition of man, both the period of discovery, and the author of this invaluable instrument, are alike involved in the deepest obscurity. It is, perhaps, a singular trait in the history of the world, that while the blood-stained brow of the ferocious conqueror, the scourge and desolator of the universe, is handed down to posterity by the descriptions of contemporary writers, and the lineaments of his countenance perpetuated to after generations by the easel of the painter; the very name of him who dedicates, to the advancement of the knowledge and happiness of his fellow-creatures, those talents with which heaven has endowed him, is allowed to moulder in oblivion with the dust and ashes of his corporeal existence. Even the very nation to which we owe its discovery is unknown. Venice, Naples, France, England, and China, have respectively claimed the honor of the invention.

Venice lays claim to it through Marco Polo, the famous traveller of the 13th century, who is said to have brought the invention with him from China, about the year 1260: this, however, is not a discovery, but the dissemination of a discovery.

The Neapolitans ascribe its invention to Flavio de Malfi, or Flavio Gioia, about the year 1302. Hence, the territory of Principato, in Naples, where he was born, bears a compass on its shield.

The French assert their claim to this disputed honor, from the circumstance of the Fleur de Lis, the national emblem, by which all nations distinguish the north point of the card: but this is far fetched, inasmuch as it may be merely a modification of the arrow-head, by which bearings are universally distinguished; or, it may be, that this distinguishing mark was first adopted by the French, and imitated subsequently by the other nations, as the most elegant device that could be employed. A French author, also, (Fauchet,) endeavors to substantiate the national claim from some verses by Guyot de Provence, one of their Troubadour poets, who flourished about the year 1200: thus placing its use in France anterior to the period of Marco Polo, or Flavio de Malfi. But the verses are obscure; and as it is unlikely such an useful instrument would lie neglected, the word "Marinette," by which he supposes it to be designated, in English "the Mariner's Stone," is most probably to be rendered by some other word, not having any reference to the subject. But if we come to words and etymology, then we fear the French claim must yield to the English; for all civilized nations call the instrument by the term Compass, a word of Saxon origin.

We are inclined, however, to accord the palm of honor to the Chinese. According to the Venetian account, it was known to them before the year 1260; and how long before that period will perhaps never be determined. If we take the chronicles of the Celestial Empire for our guide, we shall find it affirmed that their emperor, Chen

Yang, a celebrated astrologer, was acquainted with it 1120 years before Christ. This is certainly affixing a period of very high antiquity to their knowledge of the instrument; and though the chronicles of this ingenious and interesting people are supposed, (and that not without reason), to be carried back to a fictitious antiquity, yet, as they are not engaged in a dispute with the nations of Europe for the honor of the discovery, it is highly probable it has been known to them for a very long period. Now, as it was known to them in the year 1260, when Marco Polo brought it to Venice, and as we cannot suppose it was invented that year expressly to please the traveller, or his master, the Doge, it is fair to assume that it was known to them some centuries, at least, before this. We therefore think it would be as well for the nations of Europe to lay aside their claims to the honor of the invention.

Although the inventor of the Compass Needle is unknown, it is not so with the inventor of the Dipping Needle. This ingenious discovery is due, beyond all doubt, to an Englishman named Robert Norman, a compass maker at Wapping, about the year 1576. In that year, he found the dip, or inclination of the needle, at London, to be 71° 50′, being the first observation of the kind ever made.

The Dipping Needle is the only instrument, hitherto contrived, which appears capable of determining the longitude, independent of chronometric measurement; but it is doubtless more applicable to find the latitude. Were the state of the dip and variation permanent and known, the mariner would be possessed of two instruments by which he would be able to find his latitude and longitude, having determined his variation and dip by observation, by simple inspection of their indications, as compared with the same indications on the chart. This, unfortunately, is not the case. The dip, however, is not so changeable as the variation, and the variation seems at present nearly stationary; so that an accurate chart of both in one would be of the most essential service to the world, as well as of practical utility to the navigator, for many years to come.

The most remarkable improvement of the Compass is unquestionably the present mode of suspending it on a pivot, in a box playing on gimbalds. The original construction of it at Venice, was by attaching it to a piece of cork, and floating it on the surface of a bowl of water: but this is evidently liable to many objections; particularly, that in an agitated sea, for want of a point by which its motions are confined, it is subject to be tossed in very various directions, and err more materially from the meridian, not to mention the destructive effects of rust. This was the manner in which the Chinese constructed their Compass up to the year 1800, and perhaps they still continue it to the present day.

The Dipping Needle is, at present, an instrument of necessarily imperfect construction, for want of a knowledge of the cause of magnetism; but we shall show, in its proper place, the reason of the failure, and the remedy for it.

The many phenomena affecting the horizontal direction of the magnetic needle, at different periods of the day and year, were unnoticed, as well as the dip and its periodic variations, for centuries after the polarity of the magnet was ascertained; and the cause of them, as well as of polarity itself, has never been explained on known physical causes. We flatter ourselves, however, that we shall be deemed to have satisfactorily solved all these phenomena on acknowledged natural principles, together with the apparently inexplicable mysteries of magnetic attraction and repulsion, and the periodic fluctuations in the sustaining power of magnets.

As the flow of caloric from the magnetic equator to the magnetic poles is the cause we assign for the production of magnetic phenomena, the plan we have thought proper to adopt in treating the subject is to show, 1st, That the tropical caloric moves toward the pole, and dips simultaneously: the dip increasing with the reduction of terrestrial temperature, till it is vertical at the poles. 2d, That the magnetic equator is the line of greatest heat, and the magnetic poles the points of greatest cold, throughout the world. 3d, That a vertical section of the calorific current, (or the calorific meridian,) never coincides with the geographic meridian, except where the lines of no variation fall: affording a solution of the nature of the magnetic meridian, and of the lines of variation and no variation. These are the principal phenomena affecting a needle in motion toward different latitudes and longitudes.

We now come to the periodical affections of a needle, at any given locality. In order to solve these, we shall show—1st, That the calorific meridian changes its direction four times every day. 2d, That the mean of the extremes of the daily variation of the calorific meridian moves westerly from the summer to the winter solstice, and easterly from the winter to the summer solstice; causing the solstitial variation of the magnetic meridian. 3d, That the dip of the calorific flow, taken in the summer, indicates a greater angle of inclination than when taken in the winter; causing the solstitial variation of the dip. 4th, That the dip of the calorific flow, taken in the forenoon, indicates a greater inclination than when taken in the afternoon of the same day; causing the diurnal variation of the dip. 5th, That the horizontal momentum of the calorific flow diminishes from the winter to the summer solstice; causing the horizontal needle to make a greater number of oscillations in winter than in summer. 6th, That the horizontal momentum of the calorific flow increases from the morning till about the hottest period of any given day, when it is at its maximum; causing the horizontal needle to make a greater number of oscillations at that time than in the morning.

Assuming that the calorific flow acts on one end of the needle in either hemisphere more strongly than on the other; and having shown that the line of the calorific flow agrees with that of the magnetic meridian, through all the changes of the day and year; to prove which, we ask but two postulates: 1st, That caloric flows from the place of a redundancy to that of a deficiency: and 2d, That evaporation goes on at all physical temperatures: we next proceed, in the second part of our work, to explain the nature of the leading end or pole of the needle. This appears the most legitimate way of proceeding; for we should deem it useless to inquire into the mode by which caloric acts magnetically, until we had shown, by coincidence of direction, that there were good grounds on which to found our reasoning. In order to solve the nature of the polar ends of the needle, we are obliged to assume, as an hypothesis, that the ultimate particles of steel are not truly globular. Now, as there are above a million forms in nature, the chances are a million to one in our favor, which almost amounts to a certainty. Any other form but the globe will solve the problem; yet, for perspicuity's sake, we assume the angular form.

The views we have taken are perfectly new, and many of them may, at first blush, startle the reader. It may appear strange to say, that there is but one pole to a magnet, and that that pole is changed on crossing the magnetic equator; but attentive consideration will bring conviction that it is so. What so simple as *unity?* It seems the law by which nature is governed; and they who needlessly multiply causes, are only mystifying themselves and misleading others. Had the perpetual change of identity in the specific caloric of bodies, which we take notice of, been observed by philosophers, it is impossible the cause of magnetism could have remained a secret.

We know not how the theory we have advanced to account for the diurnal rotation of the earth, and other terrestrial movements, will be received by the learned world, or what reception our notions on climatology may meet with; they strike us, however, as legitimate and obvious deductions from known truths.

If we shall be deemed to have culled a flower from the regions of philosophy, whose brilliance may render it worthy of preservation in the herbarium of science; if we shall be deemed to have added a single leaf to the wreath of philosophy; or to have contributed one single truth to the stock of human knowledge; we shall feel proud in the consciousness that our time has not been unprofitably spent, and that we have contributed to benefit our fellow-creatures.

TO THE PUBLIC.

An accidental rencontre, in the early part of April, 1833, made the author of this work acquainted with Dr. Metcalf. Our ideas had always been clear respecting the identiy of caloric, electricity, and galvanism, and we were pleased to find a gentleman who coincided with us in the doctrine. As soon as the passage of caloric from the equator to the poles was assigned by Dr. Metcalf as the cause of the polarity of the magnetic needle, the truth flashed upon us in an instant: it was like the movement of the element which formed the subject of our conversation—instantaneous and irresistible. The grounds he assigned for this hypothesis were: that caloric must be flowing north and south from the equator to the poles, and that the needle takes the same direction; that the northern sections of North America were the coldest portions of the known world, and that the needle obeyed the American pole over two thirds of the northern hemisphere, (on what authority was never mentioned,) and the Siberian over one-third; and that a needle of wood, when warmed, would polarize on water: we know not, however, whether this last be true. These were the slender grounds on which the theory rested.

So convinced were we of the truth of the theory that caloric was the cause of polarity, that we labored incessantly, night and day, to bring proofs of its truth; and we cannot but regret that, notwithstanding the assistance we rendered him gratuitously, Dr. M. has never had the kindness to give us credit for even one suggestion, or even to allude to us throughout his work.

In the course of reasoning on the subject, the author was enabled to solve several important problems in support of the theory. *We* proved that the *magnetic equator* was the line of greatest heat, and that the *magnetic poles* were the *points of greatest cold*; for, when Dr. M. was reasoning on Dr. Brewster's points of greatest cold, we showed that the magnetic pole, as determined by Captain Parry, in Prince Regent's Inlet, was the point of greatest cold in America. We explained the diurnal variations of the needle by the *alternate differences* of meridianal temperature; and Dr. M., eager to appropriate it to himself, takes no notice of us, and inserts it; but not fully comprehending us, talks of *successive* heating and cooling of the *magnetic meridians in lower latitudes;* when, if he had reflected, he must have seen that they did not coincide with the terrestrial meridians, but run across them, and that, consequently, the successive action he mentions, does not and cannot take place. We accounted for the breaking up of the arctic ice by unequal expansions and contractions, and delivered it, as in many other cases, in writing: Dr. M's. explanation of the phenomenon, and his reflections upon it, are very near our own. We pointed out the influence of the variation upon the climate of northern countries, and cited the thrift and decay of the vine in England as a proof. We proved the simultaneous influence of both the northern magnetic poles upon the needle, by calculating a line of no variation, nearly coinciding with the European line of no variation, before we ever saw a magnetic chart: and though Dr. M. would not then admit of the influence of the two poles, accounting for this line by a third pole about Spitzbergen, yet, in page 112 of his work, he seems to have embraced the doctrine.

We mention these circumstances, because it might otherwise be supposed we obtained our ideas surreptitiously from Dr. M., and have used them without acknowledgment.

We know not how the world will receive our theory of the dip, as occasioned by evaporation; but we should remark that a rough sketch of it was laid in writing on Dr. M's table, (and is now in his possession), three weeks and more before he framed his; and it appears to us that the electrical part of his theory is founded on the paper above mentioned.

It is plain that we differ on fundamental points, and the learned must decide. Dr. M. considers that there are *two* forces acting on the needle—a horizontal and a vertical; that the former decreases toward the poles, while the latter is constant: that there are three magnetic poles in the northern hemisphere, and three in the southern: "that in some respects the earth acts as a great magnet, inasmuch as it imparts magnetism to substances when placed in the magnetic meridian," thus making magnetism some quality or communicable fluid of some kind; also, "that the earth attracts the needle," and "that it attracts the needle toward its centre." While we maintain, that there is but *one* force acting on the needle, and that in the direction of the dip: that the horizontal and vertical forces decrease toward the pole, but that the latter does not decrease in the same ratio as the former: that there are but two magnetic poles in the northern hemisphere, and one only in the southern: that the earth does not magnetize at all, but that caloric, *in transitu* to the earth, does: that the earth does not attract the dipping needle, but that caloric, *in transitu*, guides it in its own direction.

In a note at the foot of page 118, Dr. M. gives a mechanical solution to the direction of the needle. We have no doubt this is correct: it is our own theory. The doctor should, however, have recollected his acknowledgment that we were beforehand with him, when we read to him our theory of what a magnet is, and why hard steel is more susceptible of magnetic directive influence than other substances.

We are surprised Dr. M. has never even alluded to the new experiments we suggested, and instituted at his own desire, to prove the non-existence of a southern influence in the northern hemisphere, and *vice versa*. Yet he makes *italic* mention of another gentleman, who magnetized his pen-knife with a poker, though every one knows that fire-irons become magnetic from their usual perpendicular position. Common courtesy required some slight notice of one who labored for him gratuitously for two months, frequently till midnight. At all events, it should have procured the fulfilment of three promises, viz: the insertion, in his work, of our theory of the dip; of our explanation of the diurnal variation; and our notice and prophecy respecting the growth of the vine in England. This latter is considered by Dr. M. so important, (as it really is, in connection with this subject,) that he insists upon it three times in the course of his work.

We had concluded our solution of the variation in both hemispheres before Dr. M's work had issued from the press. We informed him of the fact, and he confessed he could not account for it, but firmly believed Professor Hansteen's chart to be entirely incorrect, especially in the Asiatic line of no variation.

The second part of our work is entirely distinct from Dr. M's, as it shows what a magnet is, and the modus operandi of the calorific flow, with a solution of magnetic attractions and repulsions. It also contains many new views on the subject of climatology.

The work now submitted to the public generally, is the same as that which was delivered before the New York public, in December 1833, in a course of six lectures, the last five of which, Dr. M. attended as an auditor.

We would have it distinctly understood, that all the reasoning contained in our work is original with ourselves. It is perhaps true, that much may be found in other works; but we have not, knowingly, appropriated another's reasoning. We should not have made the remarks we have; but when, in September 1833, Mr. Patten, mathematical instrument maker, had engaged to print this work, Dr. M. stepped in and defamed our character; on which account, Mr. Patten refused to publish. As, therefore, our work appears long after Dr. M's, it might be supposed we were using his reasoning on some points, unless we thus adverted to it. Whatever strictures we may have made on Dr. M., have been made "more in sorrow than in anger." We know what human nature is, and can make allowance for errors, which, perhaps, arise from a pardonable source.

New York, June, 1835.

AN ANALYSIS
OF
TERRESTRIAL MAGNETISM.

PART I.

In the course of reasoning on the subject of magnetic polarity, it was impossible to do otherwise than endeavor to trace the cause of the dip of the vertical needle, so intimately connected as it is with the phenomena of the horizontal needle; for it is well known that the inclination of the former increases as the intensity of the latter diminishes.

This fact for a long time created an insurmountable difficulty to its elucidation, inasmuch as polarity, being a counteracting force to its inclination, seemed to imply a different cause of attraction to produce its verticality, from that which produces its polarity; and the more so, as its cause appeared internal, by reason of its apparent tendency toward the centre of the earth. At length, however, an external cause presented itself, which, we had no doubt, was the real explanation of the phenomenon.

Considering that Dr. Metcalf had *suggested* the true cause of polarity, in assigning the passage of caloric from the equator to the poles as the agent, it struck us that another simultaneous tendency of the same agent was also the cause of the dip. But how to resolve this, is the question. It will, therefore, be necessary, in the first place, to reason on the nature of the polarity of caloric.

It has been a moot point, whether the mean temperature of the earth remains the same. We shall deliver as our opinion, that it does. We do not speak here of the violent changes which appear evidently to have taken place since the first constitution of things, nor of the mean temperature of any particular place, but of the earth as a whole; for that of particular places in different years and seasons, we know varies, which is owing to change of calorific distribution, arising from general acting causes. We maintain, that the entire volume of caloric received by any meridian during the day, is given off during the succeeding night, without taking notice of accidental causes, such as the interposition of clouds, &c.

When the sun is on the northern signs, there is an accumulation of sensible warmth on the northern half of each meridian, because the daily supply is greater than the nightly radiation and the demand for evaporation; but at the same time, the nightly radiation of the southern hemisphere is greater than the daily supply, owing to increased obliquity of the sun's rays, causing a reduction of temperature on the southern half of each meridian, corresponding to the increase on their northern halves.

But it may be inquired, from whence is the caloric received, and where does it radiate? The sun, as the fountain of warmth, radiates its heat into space in all directions, and each planet, consequently, intercepts, in its passage, a volume of caloric contained in a cone, whose apex is at the centre of the sun, and whose base is the section of the planet and its atmosphere, taken perpendicular to a line joining its centre with that of the sun: we shall denominate this the cone of *reception*, because through this cone caloric is *received* by the earth. There is consequently an illimitable truncated cone beyond, deprived of its due supply from the sun direct. But the diurnal revolution of the earth, bringing the heated meridians successively toward it, they give off the intercepted caloric, which continues its course in this cone into space in the same direction it would have taken if given off from the sun direct. We shall designate this the cone of *transmission*, because caloric is *transmitted* to it from the earth. So that the mean temperature of all the meridians remains the same from day to day, and therefore the mean temperature of the earth remains the same from year to year; that is, the absolute caloric of the earth always remains the same.

It remains now only to trace the distribution of this terrestrial caloric, and we shall find that it has but two general tendencies, viz: *a polar course, in a dipping direction.* If in the middle latitudes a blade of steel be exactly balanced, and suspended by a silk-worm's thread, and then touched with a magnet, one end will turn toward the pole of the hemisphere where it is situated, and dip: if it be brought toward the tropics, the dip will diminish, and vanish at the magnetic equator, the instrument becoming horizontal there, as before it was touched: if it be brought toward the circles, the dip will increase, till the needle becomes perpendicular at the magnetic poles. Now we can prove there is a calorific current from the magnetic equator to the magnetic poles; that it is horizontal at the equator, and dips toward the poles, where it becomes perpendicular. This calorific current, then, we assign as the cause of the dip and polarity of the magnetic needle, and of all other magnetic phenomena.

It appears, at first sight, on comparing the position of the dipping needle with that of the horizontal, that the former is the result of two forces acting upon it; but we shall show, *that it really results from the action of one force upon it, produced by the composition of two forces upon the agent, caloric: one, horizontal, toward the pole; and the other, vertical, toward the earth.* The horizontal force has been *suggested* by Dr. Metcalf to be the passage of caloric from the equator to the poles, and therefore it follows that it flows from and to the same medium—atmospheric air. We shall show, that the vertical force is produced *by the simultaneous passage of the same body of caloric from one medium to another, or, in other words, from air to earth, as an effort to restore a thermometric equilibrium, which is perpetually destroyed by evaporation.*

Before we proceed, however, to our proofs, we shall give the definitions of certain terms of frequent occurrence in the following pages, in order that there may be no misunderstanding as to the signification we affix to them; then assume two postulates, as the bases of all our reasoning; and state some well-known truths, which, as we shall have to recur to frequently, we shall denominate axioms.

CALORIC—The most subtle of all the elements; the cause of the phenomena of heat and cold; and, as we shall prove, of magnetism also.

We would have it distinctly understood, that we consider caloric as a material agent: but it must be confessed that most of these phenomena are explicable on the theory that heat is caused by a vibratory motion of the particles of bodies. Yet we are inclined to think that when our theory of magnetism is fully comprehended; when we shall have shown that the same laws which govern the motions of bodies in fluids and gases, will solve the phenomena of the magnet, all impartial and unprejudiced minds will concede that that hitherto imponderable agent is material, and to be weighed by means of the magnetic needle.

VOLUME—The existing quantity of caloric in any given bulk of atmospheric air, (or other body,) at any given locality, considered *per se*.

By the term volume, or calorific volume, we do not mean the specific heat of bodies, or the caloric of temperature, considered separately; but the absolute quantity existing in any body.

ABSOLUTE VOLUME—The existing quantity of caloric in any given bulk of atmospheric air, (or other body,) as compared with that of any other equal bulk of a different thermometric temperature; also, the existing quantity of caloric in any bulk of matter, as compared with that of an equal bulk of matter of a different nature, whether of the same or different thermometric temperatures.

Thus, the absolute volume of moisture of the crystals of one salt differs from that of the crystals of another kind; and that of the same crystal varies with the different states of the atmosphere. The absolute volume of caloric is analogous to the specific gravity of gases, fluids, and other bodies: it is synonymous with temperature, wherefore, the numeral expressing the temperature is also the numeral expressing the absolute volume; yet this holds good only on comparing the temperatures of any given medium, and not in comparing similar or dissimilar temperatures, in two different media.

HEAT—The relative effects of the greater of two or more absolute volumes of caloric, when tested in the same manner.

COLD—The relative effects of the smaller of two or more absolute volumes of caloric, when tested in the same manner.

Heat and cold exist in fact only in relation to each other, and signify merely different absolute volumes of caloric, in equal bulks, of the same or of different substances, under the same circumstances. They are absolutely convertible terms. Often, when the thermometer indicates a temperature of 52°, we exclaim "How mild! how comfortable!" Let this temperature be accompanied with a drizzling rain, "How chilly it is to day!" If it rises suddenly from freezing to this temperature, we exclaim "How warm!" And if it should descend suddenly from 90° to this temperature, "How cold!" How often, also, do we feel more cold when the ice is dissolving by a process, familiarly known as a cold thaw, than when that ice was forming! The truth is, it affects us under different circumstances.

FLOW—The passage of caloric, *per se*, from place to place, as a distinct element, separate and independent of the media in which it is diffused.

That caloric has a separate motion, is undeniable; for the tendency of a heated body, suspended in the atmosphere, is to warm the air around it, and cause it to rise, by increasing its bulk: here caloric moves in combination with the air. But if the hand be held beneath the body, or aside at a distance, it will perceive a radiation or divergence of heat: this is a separate effort of the caloric itself, as a distinct element, to diffuse itself equally around. Besides, as the body is stationary, and undiminished in weight, and as the caloric passes from it into the atmosphere, it passes into it in a separate state: in other words, it has a diffusing tendency of its own.

Another familiar proof that caloric moves independently, is furnished by a common fire. If we bring a kerchief near, it will draw to the fire, while yet, at the same time, the opposite end of the room becomes warm; proving that there are two opposing currents: one of air, as fuel, toward the fire; and the other of caloric, in a contrary direction. We consider that the flow of caloric is analogous to the diffusion of a gas; that its distribution is subject to the same laws; that, being delivered by the sun, it seeks an equal diffusion; and that the greater absolute volume at the surface of the earth, and at certain times, in the middle latitudes, is proof of its materiality, as we shall prove hereafter.

The word *flow* bears the same relation to *caloric*, that *wind* does to *air*. The word prefixed shows the quarter from whence it comes; as in speaking of the winds. Thus, "equatorial flow" denotes the general terrestrial flow from the magnetic equator to the magnetic poles; "northerly flow" signifies a flow from the north; and "southerly flow," a flow from the south. But the words *northerly* and *southerly*, prefixed to *equatorial*, denote the hemisphere, which is determined by the magnetic, and not by the terrestrial equator.

MAGNETIC NEEDLE—A prismatic bar of hardened steel, which, when suspended by a silk-worm's thread, possesses the property of polarizing, (that is, turning toward certain points in the frigid zone, called the magnetic poles,) and of simultaneously dipping toward the earth.

When it is so suspended as to play only in a vertical plane, it is called the *vertical* or *dipping needle*; and when so suspended as to play only in a horizontal plane, the dip being obviated by loading the end which rises, it is called the *compass* or *horizontal needle.* All steel has not this property sensibly; but all steel may acquire it by induction, in many ways: such as passing a magnet over it; laying it for a long period in the direction in which the needle looks or dips, or in a perpendicular direction. It may acquire this property instantaneously, by striking it on the elevated end, when held in or near the direction of the dip; by letting it fall perpendicularly on some hard substance; by a stroke of lightning, an electric discharge, and many other ways. This property may also be destroyed, gradually or suddenly; or reversed at pleasure, so that the end which pointed north shall turn south: it may also be made to disappear, though actually existing, and to re-appear, at pleasure. All these phenomena will be explained, curious and singular as they seem.

POLES OF THE NEEDLE—The two ends of the magnetic needle: that which points north is called the north pole, and its opposite the south pole.

This is the general acceptation of the term; but we shall show, hereafter, that there is but one leading end, or pole, to a true needle, except in one case, viz. when it is situated at the magnetic equator; yet, as they are conventional terms for the two ends of a magnetic needle, we shall retain them. As the word "pole" is used in other senses in this science, we would suggest whether the word "eye" might not supply its place; signifying, metaphorically, that end of the needle which is directed to, or looks toward, the magnetic poles.

MAGNETIC POLES—Those points within the frigid zones toward which the needle turns.

We shall show, hereafter, that the magnetic poles are coincident with the points of greatest cold; that there are consequently flows of caloric to them from all points of the compass as to points of greatest terrestrial deficiency of caloric. We shall also show, that their situation is central with respect to the main masses of arctic and antarctic continental surfaces; and that there are two magnetic poles in the northern hemisphere, and but one in the southern.

MAGNETIC EQUATOR—An irregular line within the tropics, running east and west, where the needle polarizes, but does not dip—remaining horizontal.

We shall show, hereafter, that this line is coincident with the line of greatest heat; that, in consequence, it divides the globe into two hemispheres with respect to heat; and that there is a continual flow of warmth from this line to the magnetic poles. Neither this line nor the magnetic poles are stationary.

MAGNETIC MERIDIAN, OR PAROPSIS—The line of direction in which the needle happens to be at the line of observation; the local direction of the general equatorial flow.

As the direction of the needle changes every hour, there is no such thing as a permanent magnetic meridian; yet, for convenience sake, we assume the direction it takes at or about midnight, as the true magnetic meridian for the day; and though this direction shifts daily, no inconvenience results from it in considering the phenomena of any given day. As the magnetic needle rarely points due north, its line of direction is mostly across the geographic meridians; wherefore the term magnetic meridian seems inapplicable, as noon does not happen simultaneously along the line: we would, therefore, propose as a substitute the word "Paropsis," signifying the direction in which a needle looks to and through a certain point.

VERTICAL.—By this term we would be understood as merely signifying *downward* (from a vertex or point) toward the earth, whether perpendicularly or not; except when we speak of the sun's rays, when vertical means perpendicular.

HORIZONTAL.—By this term we would be understood as simply implying a *direction toward the polar horizon*, whether truly horizontal or not.

The following are the two POSTULATES upon which we found all our reasoning, and, consequently, the truth of our theory:

I. THAT CALORIC FLOWS FROM THE PLACE OF A REDUNDANCY TO THAT OF A DEFICIENCY, AS AN EFFORT TO EFFECT A THERMOMETRIC EQUILIBRIUM.

If any one should be so hardy as to deny the truth of this position, we would charitably condemn him to do penance at the further end of a room, with a thermometer at his side, speaking eloquently of an actual Fahrenheit's zero, and an empty stove before him: the probability is, that he would recant his error in a short time.

II. THAT EVAPORATION IS CARRIED ON AT ALL TEMPERATURES, BY THE DESCENT OF CALORIC FROM THE ATMOSPHERE TO THE SUPERFICIAL MOISTURE OF THE GLOBE.

We think no one will be inclined to dispute the reasonableness of this position. The solid ice evaporates during the rigors of a polar winter, and the vapor which rises from it is visible to the eye in the severest weather; so that aqueous evaporation takes place at all temperatures throughout the globe. The possibility of a cessation at a theoretical zero, or at other theoretically low temperatures, is not worthy of notice, as it never actually occurs.

The following are some well-known truths respecting the momentum of fluids, gases, &c.; and, as we conceive caloric to be material, they are equally applicable to its momentum: we only substitute volume for gravity, and caloric for gas, fluid, &c. We shall denominate them *axioms*, as we shall have to employ them frequently.

Axiom I. *That the product of volume and velocity constitute the effective force or momentum of a calorific current.*

Axiom II. *That a given bulk of caloric, of any given absolute volume, moving with a given velocity, acquires a greater momentum than an equal bulk of less absolute volume, moving with the same or with less velocity.*

Axiom III. *That a given bulk of caloric, of any absolute volume, will move, under similar circumstances, with greater velocity through a rare than through a dense medium.*

Axiom IV. *That the vertical influx of a body of caloric, of any given absolute volume, into an atmosphere of caloric of the same (or less) absolute volume as itself, will displace an equal bulk of that atmosphere, and cause a mechanical movement of an equal bulk from each side of the point or line of influx.*

The following beautiful truth was established by the ingenious Mr. Dalton, and we shall assume it as an axiom.

Axiom V. *That the capacity of the atmosphere to sustain moisture increases or decreases in a geometrical ratio with the arithmetical increase or decrease of temperature.*

Before entering on our calorific or magnetic theorems, it will be necessary to prove certain lemmas respecting the momentum of a calorific flow along an imaginary line, in a homogeneous medium, under different circumstances: supposing, always, the point of calorific excess or of maximum absolute volume at the point of linear bisection, and that it diminishes uniformly toward the points of destination, or minimum absolute volume, at the extremities of the line. It will also be necessary to prove certain lemmas respecting the momentum of the calorific current of evaporation.

Lemma I. *That when there is no incoming supply of caloric, and the medium of transmission is of uniform density throughout, the volume and velocity of the calorific current is in direct proportion to the difference of temperature, or absolute calorific volume at the spot of observation, and at that of its ultimate destination; and its initial velocity is in direct proportion to the density of the medium of transmission.*

For, as the difference of absolute volume, between any two places, causes the flow, (*Post. I.*) as an effort to restore the equilibrium, therefore the greater the difference, the greater the absolute volume transmitted, before the object can be accomplished. As this volume is set in motion by the difference of absolute volume at any two places, the greater the difference the greater the velocity with which it is transmitted. Also, if the medium of transmission be rare, the calorific current will move through it with a certain initial velocity; but (*Ax. III.*) if the medium be increased in density, (supposing its nature and the absolute volume of the current the same,) the current will be retarded in its initial progress in direct proportion to the increase of density in the medium. Wherefore, &c.

The increase of the volume transmitted and of its velocity is, in fact, strictly analogous to the passage of atmospheric air into an exhausted receiver: the more complete the exhaustion, or difference of absolute atmospheric volume between the inside and the outside of the receiver, the greater will be the absolute volume that enters, and the velocity ot that volume, on opening the valve of communication.

Lemma II. *That the momentum of the calorific current along the above imaginary line, for any number of equidistant points on either side of the point of maximum, toward either point of minimum absolute volume, is a decreasing finite harmonic series.*

For, as we suppose gradual decrements of temperature (i. e. absolute volume) along the line, the series expressing the absolute volume for any number of equi-distant points, from maximum to minimum temperature, will decrease arithmetically; also, as the volume transmitted from any point, to the point of minimum temperature, depends on the difference of absolute volume at that point, and at the point of minimum temperature; and as this decreases arithmetically, therefore the series expressing the velocity of the volume transmitted will decrease arithmetically. But (*Ax. I.*) the product of volume and velocity constitute the momentum of the calorific current; therefore, the product of these two series, term for term, is the series expressing the momentum: and as the product of any two arithmetical series, term for term, is an harmonic series, this is the nature of the decreasing series expressing the momentum: as, also, on arriving at the point of minimum absolute volume, its further progress is arrested, the last term of the series is 0, showing it to be finite. Wherefore, &c.

LEMMA III. *That when there is a steady incoming supply of caloric, vertical at the point of maximum, increasing in obliquity, and consequently diminishing in volume, toward the points of minimum temperature, when also the medium of transmission is of uniformly increasing density from and to the same points; then the series expressing the momentum of the calorific current for any number of equidistant points is also a decreasing finite series, of the same nature as in Lemma II.*

For, whatever the absolute volume at the point of maximum temperature, without any incoming supply, the addition of a supply, vertical at that point, and decreasing gradually in volume with the increasing obliquity of delivery toward the points of minimum temperature, will only increase the absolute volume along the whole line; but the temperature still decreasing gradually toward the points of minimum temperature, the series expressing the absolute volume transmitted for any number of equi-distant points from the point of maximum to either point of minimum temperature, will be a decreasing arithmetical series; also, as the delivery, at the point of maximum temperature, is vertical, therefore (*Ax. IV.*) it mechanically moves the existing volume on either side toward the points of minimum temperature; thus, there is a continual source of velocity, independent of the mere difference of maximum and minimum temperature; but as the momentum of the supply diminishes gradually in effect along the line, with the increasing obliquity, and its diminishing volume; and as the initial momentum of the existing quantity (considered at any moment) at the point of maximum temperature, diminishes with the increasing density of the medium toward the points of minimum temperature; therefore, the velocity decreases gradually to the points of minimum temperature, and the series expressing the velocity for any number of equi-distant points is a decreasing arithmetical series. Wherefore, the conditions are the same as in the preceding lemma, and the momentum is a decreasing series of the same order; the only difference being, that in this case the first term is further removed from zero than in the last; or, in other words, it is a more rapidly decreasing series. Wherefore, &c.

As the momentum of this force is exerted in a horizontal direction, we denominate it the horizontal force of caloric, or magnetism.

The above lemmas ascertain the nature of the horizontal transmission of caloric, as an effort to effect a thermometric equilibrium from the centre toward the two extremities of an imaginary line, in a homogeneous medium, increasing uniformly in density to those extremities; such, for instance, as from the equator to the poles, along a meridian. We shall now assume some more conditions, of a different nature, in order to unfold the consequences of evaporation, or a vertical flow.

Let there be another medium, homogeneous throughout, and of greater specific gravity than the former, so that it cannot coalesce with it, but must remain subjacent as a distinct medium, and receive its caloric by transmission through the rare superincumbent medium: let it be of such a nature that the combination of caloric with it will increase its bulk, and thus diminish its specific gravity, and cause it to rise from its former level into the medium of calorific transmission: and let the former imaginary line be the boundary line between the two media. The atmosphere and the superficial moisture of the globe are under the above conditions.

Lemma IV. *That the bulk of moisture converted into vapor is in direct proportion to the quantity of caloric transmitted to the surface.*

For, as evaporation is carried on by the combination of caloric with the moisture of the surface, the greater the quantity that combines, the greater is the bulk of moisture converted into vapor, and the less the quantity that combines, the smaller the bulk of moisture converted into vapor. Wherefore, &c.

Cor. 1. *That equal bulks of caloric, of equal absolute volume, will convert equal bulks of moisture into vapor.*

For equal bulks, of equal absolute volume, contain equal quantities of caloric; and equal quantities of caloric convert equal bulks of moisture into vapor. Wherefore, &c.

Cor. 2. *That equal bulks of caloric, of unequal absolute volumes, convert unequal bulks of moisture into vapor; the ratio of conversion being as the quantities of caloric in the two bulks.*

For, equal bulks, of unequal absolute volumes, contain unequal quantities of caloric, and by the lemma, the ratio of conversion is as the quantity transmitted to the surface for that purpose. Wherefore, &c.

LEMMA V. *That the series expressing the volume of caloric transmitted by the superincumbent medium to the subjacent moisture, for any number of equi-distant points, on either side of the point of maximum temperature, is a decreasing geometrical series; as is also the series expressing the velocity of transmission.*

For, as the temperature decreases arithmetically from the point of maximum to either point of minimum temperature, therefore, (*Ax. V.*) the capacity of the atmosphere to sustain moisture decreases along the line in a geometrical ratio; but (*Lem. IV.*) the bulk of moisture converted into vapor is in direct proportion to the volume of caloric transmitted to the surface of the moisture; therefore, the series expressing the volume transmitted decreases in a geometrical ratio from the point of maximum temperature: also, as a geometrical increase of evaporation (*Lem. IV.*) is affected by a geometrical increase of volume transmitted, this must be attended with a geometrical increase of the velocity of transmission; for the lower strata of the superincumbent medium would be reduced in temperature continually, unless the speed of delivery kept pace with the rapidity of absorption. Wherefore, &c.

LEMMA VI. *That the momentum of the calorific current of evaporation, for any number of equi-distant points from the point of maximum to either point of minimum temperature, is a decreasing infinite geometrical series.*

For, by the last lemma, each series expressing the volume and velocity of the calorific current of evaporation is a decreasing geometrical series; but (*Ax. I.*) volume and velocity constitute the momentum of the calorific current; wherefore, the product of these two series, term for term, is the series expressing the momentum; but the product of two geometrical series is also a geometrical series; also, as evaporation (*Post. II.*) goes on at all temperatures, and as there is no end to the decrease of temperature, the series is infinite. Wherefore, &c.

As the momentum of this current is in a vertical direction, we denominate it the vertical force of caloric or magnetism.

As the earth is spherical, and as the sun is never vertical beyond the tropics, any given tropical surface receives a greater supply of caloric from the sun direct than an equal arctic surface; wherefore, there must be a difference of temperature, or absolute calorific volume, between the equator and the poles. But, caloric flows from the place of a redundancy to that of a deficiency; hence, a constant endeavor, by the spread of caloric from the former to the latter, to equalize the atmospheric temperatures of each. Yet this can never happen; because, as the polar regions, on account of the obliquity of the sun's rays when above the horizon, and their long winter, are always receiving less caloric, and radiating proportionally more than the equatorial, the latter will always have a redundance. The difference of equatorial and polar temperature is, therefore, the cause of a perpetual current of caloric, tending in a horizontal direction from the equator to the poles.

Whatever the temperature of the air, evaporation is always going on, but this is effected only by the agency of caloric, which is transmitted through the atmosphere to the superficial moisture of the globe, and, as this takes place in a vertical direction, it gives rise to a vertical force affecting the caloric of the atmosphere.

Thus, the whole body of terrestrial caloric is acted on by two forces: one, vertical, toward the earth; and the other, horizontal, toward the pole; and, therefore, its course is determined by their composition, which must consequently be in a polar direction, dipping toward the earth. It is our object to prove that this general terrestrial flow is the cause of the polarity and dip of the magnetic needle, in the same manner that a stream of water, or a current of air, would direct a vane; and that a magnet is but hardened steel, of a nature to obey a calorific flow. This active current is most likely given off in an electrical manner, but is invisible, even in the night, by reason of the similarly electrified state of the surrounding medium: and, as it is directed to the points of the most unequal distribution, it carries the needle with it (why, and how, will be explained in Part II. of this work) in those directions which we, for distinction's sake, denominate the north and south.

That we may avoid all intricacy, and render the subject as clear as possible, we shall consider the surface of the globe as even, and uniform in substance, with moisture plentifully distributed throughout it. We shall consider the annual and diurnal path of the sun in the ecliptic, as coincident with the terrestrial equator, (a condition agreeing with the situation of the sun at the equinoxes;) that the terrestrial equator is consequently the line of greatest heat, and the terrestrial poles the points of greatest cold; that the former is the magnetic equator, and that the latter are the magnetic poles; that the equatorial flow never deviates from the geographic meridians; that the atmosphere is stationary, and of uniformly increasing density from the equator to the poles; and that the sensible temperature or absolute volume of atmospheric caloric decreases uniformly from and to the same points.

We know that all this is not the case; but as it does not affect the truth of the principle, and as it avoids complicated calculations in the outset, we prefer this mode of proceeding. We shall make the proper inferences with respect to the path of the sun in the ecliptic, the actual disposition of land and water, the altitude of the land, the different capacities of various soils and surfaces for caloric, the effects of calorific, aerial and marine currents, when once the main principle is established.

We shall now assume the sun as vertical to any given meridian on the surface of the globe; and imagining the vertical plane of that meridian produced to the confines of the atmosphere, we shall trace the course of the equatorial flow in this plane from the equator to the pole in the northern hemisphere. The meridian above mentioned is in an analogous situation to that of the imaginary line in the lemmas we have just established, being the boundary line between two media, air and water: the sun is vertical to the equator, or point of linear bisection, and the poles are the points of minimum temperature.

From the preceding considerations, we deduce the following theorems:

Theorem I. *That the whole volume of caloric between the equator and the poles, as points of greatest cold, is subject to two forces, a vertical and a horizontal.*

For, (*Post. I.*) caloric flows from the place of a redundancy to that of a deficiency, so that the whole body of caloric, at the equator, has a tendency to reach the higher latitudes, that is, it has a tendency to travel horizontally toward the magnetic poles; and as the lower atmospheric stratum is continually parting with its caloric, by transmission to the superficial moisture of the globe, for the purpose of evaporation, so, to restore the equilibrium, it borrows a portion of caloric from the next superior stratum, which borrows, in its turn, and thus affects the whole. Wherefore, &c.

Theorem II. *That the horizontal transmission of any volume of caloric, from the equator to the poles, is not truly horizontal, but deflected downward by the vertical absorption of the earth (superficial moisture.)*

For, if the vertical absorption of the earth (*Theor. I.*) affects the calorific equilibrium of the superincumbent stratum of air, it is restored by the descent of the next superior stratum, which is thus diverted from the horizontal line of its direction; and, of course, each superior stratum is similarly affected. Wherefore, &c.

Theorem III. *That the vertical transmission of any portion of caloric (except at the poles) is deflected from the perpendicular by the horizontal influence.*

For, as the surface of the globe absorbs the caloric above it, if that caloric were stationary, it would descend to the points of absorption perpendicularly; but, as it is already in motion toward the poles, the horizontal force carries it forward, and thus affects the verticality of its descent. At the pole there is no horizontal force, and, consequently, it descends perpendicularly. Wherefore, &c.

Theorem IV. *That the course of any volume of caloric, in transitu from the equator to the poles, is in a line dipping or descending toward the polar horizon.*

For, as the whole body (*Theor. I.*) is acted on by two forces, one vertical, tending perpendicular to the surface of the earth, and the other horizontal, tending parallel to the same surface, toward the poles, it can go in neither of these directions exactly, but, according to the law of the composition of forces, it will take some angle between these directions, that is, a polar course, dipping toward the earth: the greater the vertical force, compared with the horizontal, the greater the dip or inclination of the calorific flow; and the greater the horizontal force, compared with the vertical, the less will be the angle of the dip. Wherefore, &c.

Theorem V. *That each of these forces is at its maximum intensity at the equator, and at its minimum intensity at the pole.*

For, each of these forces is (*Lem. III.* and *VI.*) a decreasing series from the equator to the pole. Wherefore, &c.

Theorem VI. *That the power or intensity of the calorific flow is greatest at the equator, and least at the poles.*

For, by the last theorem, the power of each force, considered separately, is greatest at the equator and least at the pole; wherefore, also, their conjoint power or intensity is greatest at the equator and least at the pole. Wherefore, &c.

Theorem VII. *That the vertical force is of less intensity at the equator than the horizontal, but that the former gradually gains upon the latter, in relative intensity, in advancing toward the pole, where it is paramount; so that the dip of the calorific current increases from the equator to the poles, where it is perpendicular.*

That this is so, will not bear a question, whatever the nature of the two forces which govern it, from the fact that the needle is nearly horizontal about the equator, proving that the horizontal force affecting it is greater there than the vertical; while in advancing toward the pole, the dip of the needle increases, proving that the vertical force is gaining, either absolutely or relatively, on the horizontal; at length it dips 45°, showing that the vertical force has approached to an absolute equality with its superior; in advancing farther, the dip increases, proving that the vertical force exceeds the horizontal; and at the pole the needle is perpendicular, (we assume this hypothetically, as it has been observed to dip more than 89°,) proving that the vertical force is there the only existing force; for the needle could not be perpendicular if there were the slightest horizontal force.

As the needle is well balanced, before it is subjected to the influence of magnetism, it seems at first sight contradictory that the angle of the dip, or the destruction of the physical balance of the instrument, should increase from the equator to the poles, on the supposition that the equatorial flow is the cause of it; because we have already shown that the power of both the horizontal and vertical forces, affecting the motion of caloric, (the confluence of which we conceive to be the magnetic power,) decreases in advancing from the equator. It seems more natural to suppose that the horizontal force only decreases, as indicated by the horizontal needle, while the vertical force is constant or increasing; either of which conditions will solve the phenomenon of the dip. It is evident, however, that two decreasing series will effect the same end, viz: the increasing verticality of the flow subjected to their influence, provided we can show that the first or equatorial term of the series expressing the horizontal force is a greater numeral than the first term of the series expressing the vertical force, and that the former series decreases more rapidly than the latter. Now this can be done.

If we conceive the sun vertical at the equator; that the temperature or absolute volume of caloric at the boundary line of the atmosphere and the superficial moisture is 85°; and that the vertical supply of caloric by the sun is suddenly suspended; then the vertical force at the equator (*Ax. I.* and *V.*) is determined by the proportion of the specific volume expended at that temperature in evaporation, multiplied into its velocity; and the horizontal force at the equator (*Post. I.* and *Lem. I.*) is determined by the proportion of the same specific volume requisite to equalize the polar and equatorial temperatures, multiplied into its velocity. It is of no consequence, in this case, which force is the greater: we will grant, however, the vertical to be superior.

Now, let the vertical supply flow again; (*Ax. III.*) it will displace an equal bulk of the existing volume, and occupy its place; but the temperature will not be reduced, proving that the absolute volume delivered at the equator is at least equal to the existing volume causing a temperature of 85°. As the temperature is not altered, neither is the rate of evaporation, that is the volume absorbed by the moisture, and its velocity. But the volume and velocity of the horizontal force are now greater than the volume and velocity of the vertical force: the volume is greater, because it consists in the whole of an absolute volume of 85°, while that of the vertical force is but a proportional part of an equal absolute volume; and the velocity of that volume is greater, because the vertical transmission of caloric is affected quicker through atmospheric air than through water; besides which, it must be remembered, that it is not the speed of the solar delivery which determines the amount of evaporation, but the temperature of the atmosphere; and as the solar delivery displaces an equal bulk, (or nearly so) its momentum is wholly resolved upon the atmospheric caloric. But (*Ax. I.*) the product of volume and velocity constitute the momentum of the calorific force, therefore the first or equatorial term of the horizontal series is greater than the first term of the vertical series.

But (*Lem. II.*) the series expressing the momentum of the horizontal force is a decreasing *finite* series; and (*Lem. VI.*) that expressing the momentum of the vertical force, is a decreasing *infinite* series. Hence, though each series perpetually loses in *absolute* intensity, yet the terms of the latter are always gaining in *relative* intensity upon the analogous terms of the former. For the horizontal force is constantly approaching the verge of annihilation, while the vertical force, it is true, is as constantly diminishing, but without the remotest possibility of extinction. Hence, also, the horizontal force will decrease, and the vertical force increase, in *relative* intensity, till they become equal, when the vertical force, which was the weakest, becomes the greater power of the two, though itself diminished; and on arriving at the magnetic pole, the horizontal force vanishes, and the vertical remains triumphant.

Wherefore, by the laws governing the composition of forces, the existing volume of caloric, *in transitu* toward the pole, is continually deflected, by the *comparatively* increasing vertical force, more and more from the horizontal; and the physical balance of the instrument, supposing it subject to the flow, is perpetually disturbed in an increasing ratio, by two diminishing, but yet effective forces, resolving their powers continually in a direction approaching more and more to the perpendicular. Wherefore, &c.

We have taken no notice of the exact nature of the two series. It is sufficient, that one is *finite*, and the other *infinite*. The ratio of decrease will only affect the distance from the equator, where the terms of equal power fall, and consequently the latitude of the dip of 45°.

Theorem VIII. *That the resulting course of any portion of caloric is not a right line, but a curve, whose nature may be mathematically explained, though for all common purposes it may be considered a right line.*

For, as the vertical force is constantly increasing, (relatively) and the horizontal as continually decreasing, (relatively) it follows that the course of any portion of caloric is deflected more and more toward the greater power; that is, it forms a curve, for a right line could only result from the composition of two constant ratios of power. The curvature would increase from the equator, where the flow is horizontal, to the dip of 45°, and decrease from thence to the pole, where the flow is perpendicular. As in any portion of these curves, in which the needle plays, the deviation from a right line cannot be appreciated, for all common purposes we may consider them right lines. Wherefore, &c.

Theorem IX. *That consequently only one force is exerted on the magnetic needle, which is the result of the two forces acting on the equatorial flow (or the caloric of magnetism) at the place where the magnetic needle is situated.*

For, as every volume of caloric is acted on by two forces, tending in a rectangular direction with respect to each other, whose composition produces a force imparted to it in one direction only; it results that every volume of caloric constitutes a force acting in one direction only, which consequently affects the needle in one direction only. Wherefore, &c.

Theorem X. *That the direction of the magnetic force is indicated by the dipping needle, and not by the horizontal; as are also the relative intensities of the two forces which constitute magnetism.*

For, magnetic caloric moves in a line inclining more and more to the perpendicular in advancing toward the poles; and as the dipping needle (not the horizontal) takes the same course, it is the index of the direction of the magnetic force; and as this direction is the result of the composition of a horizontal and vertical force, the angle which it makes with the horizon below is the comparative measure of the vertical force, and the angle which it makes with the perpendicular, toward the pole, is that of the horizontal. Wherefore, &c.

It is evident from this, that we have a practical means of arriving at a correct knowledge of the absolute force of the magnetic current, in any given place. By a dipping needle, constructed as a steelyard, we may measure the absolute intensity of the vertical force; then as the angle of vertical intensity, is to the angle of horizontal intensity, so is the vertical power to the horizontal power.

Having shown that every particle of caloric at the equator travels from thence toward the poles in a dipping direction, and inclines more and more to the perpendicular as it approaches the poles; and it being confessed that a well-poised blade of steel, when magnetized, dips and turns in the same direction, increasing the angle of its inclination as it approaches the poles, are we not warranted in holding, that the equatorial flow is the cause of the dip and direction of a magnetized blade of steel? Is it not a fair inference, that there is no *attraction* at the pole, which draws the needle to it; but that the impulse and direction of this external agent, caloric, as a distinct element, acting mechanically upon it, turns it in the direction of its own course, which is toward the pole, downward? It is, at least, very strong presumptive evidence.

When we see the log float down the stream, we do not for an instant doubt the reason of it: we attribute its motion to the action of the water. And if we shall be able to show, in this treatise, that the needle assumes every direction that caloric takes, throughout all latitudes and longitudes, through all the changes of the hours of the day and of the months of the year, and through all the obstacles which localities present; if, by means of this all-pervading element, we shall be able to solve that difficult problem, the variation, and every phenomenon which attends the needle, and reveal the nature of the hitherto mysterious magnet; if we shall show that its motions and directions are sympathetic and synchronous with those of its hypothetic cause; there can then, we think, remain no doubt that one of the hitherto unfathomable mysteries of nature is brought to light, and that the "great unknown" is traced to its origin.

Having thus proved, and, we hope, satisfactorily, the several propositions with which we set out, showing that the needle is only affected by one force, we shall now proceed to investigate the nature of terrestrial magnetism in general, considering the actual constitution of the globe. We shall explain the nature of the magnetic equator and magnetic poles, and then proceed to the subject of the variation, tracing the causes of the known direction of the lines of variation and no variation, and explain the causes of the many curious phenomena attending the magnetic needle.

Before entering, however, on these intricate subjects, it will be proper to notice the chart at the commencement of this work. It is a compilation, in one, of M. Hansteen's two charts of the Dip and Variation, and is taken from the Edinburgh Philosophical Transactions, Vol. IV. We have added another course to the magnetic equator, from lon. W. 96° to 120°, on the authority of a French writer, whose name is unknown to us; and we have no doubt it assumes this position, at least at the equinoxes. The magnetic equator cuts the terrestrial equator about lon. 25° E., in Africa, proceeds south-westerly through that continent, on emerging from which it makes its greatest southerly declination in the South Atlantic, about lat. 14° S., lon. 26° W.; passes north-westerly through South America, which it leaves about lat. 4° S.; meets the terrestrial equator about lon. 96° W., along which it courses to lon. 120° W.; descends southerly again toward the Marquesas islands; and rising north again, cuts the terrestrial equator about lon. 175° W.; rises gradually north, cutting the north of Mindanao, touching the north of Borneo; passes on through Malacca and Ceylon; cuts Hindoostan just north of Cape Comorin; reaches its greatest northerly declination about lat. 11° N., in the Arabian Gulf; enters Africa just south of Cape Guardafui, and descends again to lon. 25° E., the point of intersection, from which we set out. This will be its general direction, as we shall shortly see, and we must not expect an accurate knowledge of its situation at present.

We have laid down the American magnetic pole in Prince Regent's Inlet, about lat. 72° 30′ N., lon. 92° W., as determined by Capt. Parry, from actual observation, being its summer situation; and also in lat. 70° 30′ N., lon. 96° W., as determined by Capt. Ross, from actual observation, being its winter situation, or south-westerly of its summer position. We have also laid down the Asiatic pole about lat. 74° N., lon. 100° E. This is merely by estimation, and cannot be depended on, though we think it cannot be far from the truth: the error will, most probably, be found hereafter in having placed it too far north. We have also laid down the meridian of 10° W., in the southern hemisphere, on or near which we conceive the only magnetic pole of that hemisphere to be situated; and have also added some of the peculiar points of variation north of the American pole, as determined during the late polar voyages.

For the information of those readers to whom this Chart may be a novelty, we shall mention, that the lines running in the same general direction as the magnetic equator, are the lines of equal dip, and the figures at their ends denote the number of degrees that a needle dips from the horizontal toward the earth, along those lines to which they belong. The other lines are those of variation and no variation; and their figures denote the number of degrees that a needle any where on them varies from the terrestrial pole. We would recommend, in studying what ensues on the variation, that the lines of no variation and the magnetic equator be transferred to a globular projection of the eastern and western hemispheres, and also to one of the northern and southern hemispheres, where the mountains are laid down, and the meridians meet. This will render the subject much more easy of comprehension, and particularly, with the absence of the variation lines; for, when once the aberration of the lines of no variation from the geographic meridians is properly understood, the nature and direction of the variation lines will be a matter of no difficulty to understand.

All our reasoning has proceeded, hitherto, on the hypothetical assumption that the surface of the earth was even and uniform in figure and substance. The consequence of this would be, the coincidence of the magnetic equator, or line of greatest heat, with the terrestrial equator; of the magnetic poles, or points of greatest cold, with the terrestrial poles; and the absence of all variation. But this is not the case: for the disposition of the land is into two principal portions, the eastern and western continents, of very irregular and dissimilar figures, and of varying altitudes and soils, with two vast oceans between them, and with an ocean to the north of the eastern continent, (America extending so far north, its northern waters are not worth notice, and we refer only to the northern hemisphere.) Now, as Dr. Metcalf has *suggested*, that the direction of the horizontal needle is from the tropics to the frigid zone, it remains to determine from what part of the tropics, and to what parts of the frigid zones the needle is directed, in either hemisphere. It is evident the disposition of the surface of the globe must materially influence the position of the line of greatest heat within the tropics, from whence proceed the two grand terrestrial flows, the one north, and the other south, toward the frigid zones, as an effort to equalize the equatorial and polar atmospheric temperatures: it will, also, evidently affect the position of the coldest points in the frigid zones.

We shall now show, that the line of no dip or magnetic equator, is the line of greatest heat, and cannot coincide with the terrestrial equator; and that its situation depends on the relative disposition of land and water with respect to the terrestrial equator. It has been laid down by several authors, none of whom agree exactly, and the reason is obvious, if it be the line of greatest heat, because their observations were taken at different periods of the year.

As a general remark, the land within the tropics is warmer than the ocean, because it is stationary, and without a sufficiency of moisture to pass off its redundant caloric in a latent state. Consequently, that spot of land which is farthest removed from the cooling influence of the tropic ocean is a *point of greatest heat.*

When, therefore, the continent lies on the equator, its point of greatest heat will be on or near the centre of its equatorial breadth; and a line drawn through this point, and continued easterly and westerly, through the greater breadth of the land, (having respect for proximity to the equator, situation of mountains, &c.) will form *a line of greatest heat*; being warmer than a shorter line across the equator, because many of the points of longitude in the former are farther removed from the cooling influence of the ocean than the corresponding points in the latter; which, in those regions, more than compensates the increase of latitude. This is exemplified in the path of the magnetic equator through Africa, where it cuts the terrestrial equator about lon. 25° E., which is the point of greatest heat, and continues diagonally north-east and south-west of it.

When the far greater bulk of the continent is beyond the equator, the line of greatest heat will be found on that side, far from the equator, as exemplified in its path through South America, running diagonally from about lat. 11° S., on the east, to lat. 4° S. on the west.

When the whole continent is far removed from the equator, the line of greatest heat will be considerably deflected from the equator toward the continent, and pass over the ocean; as exemplified in its path with respect to the Asiatic continent.

In an extensive equatorial archipelago, it is deflected on either side in proportion to the influence of the land; as exemplified from about lon. 120° W., to lon. 120° E.

Where there is an open sea at the equator, uninfluenced, or equally influenced on all sides by the proximity of land, the line of greatest heat takes its natural course, being coincident with the terrestrial equator; as exemplified from about lon. W. 96°, to 120°.

The great southerly declination of the magnetic equator, or line of greatest heat, in the South Atlantic, is owing to the influence of the great western stream, commencing on the west coast of America, which, after doubling the Cape of Good Hope, proceeds northerly by the south of Cuba, into the Gulf of Mexico. This stream acquires considerable warmth, by its long tropical course, and thus causes an unnatural southerly temperature in its northerly path through the South Atlantic.

These are the grand modifying causes, producing the devious direction of the magnetic equator, or line of greatest heat; but it is also liable to other causes of modification. It is evident, the path of the sun in the ecliptic materially affects the position of the line of greatest heat. The diminishing obliquity of the ecliptic, at the rate of about 55″ in one hundred years, tends to diminish its annual northerly and southerly declination. The nutation of the earth's axis, also, will have on effect on it; but these two latter causes are annually inappreciable. The general direction of aerial and marine currents will also have some effect on it; and the elevation and direction of the land will affect it materially, as will also the nature of the soil.

Thus, the magnetic equator is continually shifting, and is chiefly affected by the path of the sun in the ecliptic. It will, hereafter, be a curious matter of research to determine what we might denominate *the magnetic tropics*, or the greatest annual northerly and southerly declination of the line of greatest heat. The band included between them might, for distinction's sake, be called *the magnetic torrid zone;* and the mean of the two, might be considered as the true magnetic equator, which would correspond to its situation at the equinoxes.

The lines of equally diminishing temperature, or of equal dip, will, of course, take the same general direction as the magnetic equator, or line of greatest heat; but the detail of their direction will, like that of this latter, depend also on the disposition of land and water in proceeding toward either magnetic pole, as will be more clearly shown hereafter, when we treat on the subject of Climatology. We shall, however, mention here one fact, which very strongly connects the state of the dip with the state of the atmospheric temperature, as affected by a marine current: we are surprised it did not suggest itself to the mind of M. Hansteen, when he compiled his chart. As it is, he has unwittingly furnished us with an unanswerable proof of the truth of the theory. On adverting to the chart, we find, that the line denoting a dip of 70° on leaving the eastern coast of America, and approaching lat. 40° 30′ N., long. 60° W., leaves its course and descends a little south to about lat. 39° N., long. 50° W., when it rises again in its progress toward Europe. Now, it happens that this is in the neighborhood of the Gulf Stream, near its northernmost course, where a change of atmospheric temperature is known to take place. It is, to say the least, a very remarkable coincidence.

In advancing from the magnetic equator, there is a point where the needle dips 45°, being occasioned by the equality of the two powers affecting the calorie of magnetism. This point being traced round the globe, by actual observation, would form a very irregular line, dependent on the disposition of land and water, which may be denominated the *line of iso-magnetic intensity.* It must shift northerly and southerly with the path of the sun in the ecliptic, and the band included between its greatest equatorial inclination and declination may be called the *zone of iso-magnetic intensity.* Its mean may be considered the true line of iso-magnetic intensity, corresponding to its situation at the equinoxes.

The zone included between the zone of iso-magnetic intensity and the magnetic torrid zone, may be denominated *the zone of horizontal intensity;* because there the horizontal exceeds the vertical intensity.

The magnetic poles, or points of greatest cold, are not coincident with the terrestrial poles, but are dependent on the relative disposition of land and water in and near the arctic and antarctic circles; modified, again, by the path of the sun in the ecliptic, and by other adventitious causes. As a general remark, the land in these regions is colder than the ocean, because, though the supply of caloric to each by the atmosphere is equal, the former is continually cooling by radiation and evaporation, while the latter, being a shifting body, is as constantly receiving the warm currents from the tropics, and so maintains a more equable temperature.

That point, therefore, of the arctic land, farthest removed from the warming influence of the Arctic ocean, and of the land on the equatorial side of the circles, is the point of greatest cold, or of minimum absolute volume of caloric. As there are two continents in the northern hemisphere extending into the arctic circle, so there are also two points of greatest cold or magnetic poles; one in North America, and the other in the north of Asia.

As caloric flows from the place of a redundancy to that of a deficiency, there will be flows of caloric to these two points from all points of the compass, tending toward opposite directions. The equatorial flow will move northerly; that from the regions north of the points of greatest cold, in flowing to them, will take a southerly direction; that from the east will take a westerly, and that from the west an easterly direction; dipping, as they advance, with the relatively increasing vertical power, till they meet silently and without conflict, by terminating their career in true perpendicular lines downward to the terrestrial points of greatest cold. This must be borne in mind, as it will be found to correspond exactly with the state of the variation and dip of the needle in high latitudes.

The same reasoning which proves that there is a line of greatest heat passing through the points of greatest heat within the tropics, will also prove there must be a *line of greatest cold* passing through the *points of greatest cold* within the circles, of very irregular path, depending on the disposition of land and water. This line may be traced round from one pole through the other, to itself again; and might be called the *line or circle of magnetic confluence;* because, as we shall show hereafter, there is a confluence of two magnetic powers or currents to this circle. This line will shift, together with the poles, with the path of the sun in the ecliptic, and the band included in its greatest equatorial inclination and declination may be denominated the *magnetic polar zone;* because it depends on the position of the magnetic poles.

The zone included between the magnetic polar zone and the zone of iso-magnetic intensity, may be denominated *the zone of vertical intensity;* because there the vertical exceeds the horizontal intensity.

Arctic America presents nearly three times as great a continental surface as arctic Asia: its centre, therefore, is farther removed from the warming influence of the Arctic ocean, and consequently, far colder than that of Asia. In accordance with this, we find that it governs a far greater number of degrees of longitude; that is, it requires the warmth of many more degrees of equatorial longitude to restore the equilibrium of temperature than arctic Asia does. It is on this account that we see the needle vary westerly at England, and nearly as far east as long. 45° E. of Greenwich, on the old continent; this portion of the continent not obeying its natural pole, the Asiatic, because of the unequal intensities of the two poles of this hemisphere.

It is a singular fact in connection with this subject, that the temperature *north* of the magnetic pole is milder than *at* the magnetic pole itself, as ascertained by the observations of Sir E. W. Parry; to which we may add, that a continued north wind invariably brings on a thaw in the north of Europe and Asia, according to the Hon. D. Barrington's and Capt. Scoresby's information in those parts. Also, we may add, that the morse fishers in these parts, on sailing 60 or 70 miles north, in the month of March, throw off their winter clothing, but are obliged to resume it on approaching land, even at the end of May.

As the needle is not governed by the terrestrial pole, but by two cold poles south of it, one in each continent; as arctic America extends farther north than arctic Asia; and as the oceans of these regions are warmer than the land; it follows, that though the terrestrial pole is milder than either magnetic pole, yet it is colder than a spot situated somewhere between itself and the Asiatic magnetic pole. This spot, then, will form *a centre of greatest polar warmth*, from whence the caloric of those regions, emanating from the waters supplied by the equatorial currents, will spread toward *the circle of magnetic confluence*, and joining the equatorial flow of atmospheric caloric, will converge with it to the magnetic poles, or points of greatest cold, which form two points in this circle. This point, which of course varies with the seasons, we shall designate the *centre, or pole of neo-magnetic intensity;* and the zone it governs, the *zone of neo-magnetic intensity:* because the force of magnetic intensity is here renewed. It might be divided into other zones, but we prefer considering it as a whole.

These are the divisions of the globe, considered magnetically with respect to the reciprocally varying powers of the vertical and horizontal tendencies, as affected by the disposition of land and water, and the solstitial motion of the sun in the ecliptic. It may be well to remark here, as a corroborative argument for the calorific theory, that the lines of equal dip are coincident with the iso-thermal lines, or lines of equal mean temperature. This was first observed by the philosophic Baron de Humboldt.

The transmission of caloric from the waters of these regions can neither be considered as radiant or reflected, but as divergent heat. We believe these terms have as yet no settled meaning, and therefore, we have the right of giving here the meaning we affix to their use, in order to prevent cavilling.

By *radiant heat*, we mean the delivery of the solar supply of caloric by the diurnal rotation of the terrestial meridians to that conical section of space which is deprived of it from the sun direct. Consequently, heat radiates from any spot of the globe, only between sun-set and sun-rise, and one half the globe only radiates caloric at a time; that is, radiation goes on only when the sun is below the horizon. Thus, *change of identity, and not increase of quantity*, is what the solar delivery accomplishes. In radiating, caloric takes two directions: as in entering the atmosphere, it converges to the earth; so in radiating, it diverges from the surface of the earth in perpendicular lines to the confines of the atmosphere; on leaving which, it is deflected into the cone of transmission, in the same line it would have pursued if not intercepted by the earth.

By *reflected*, or *resilient heat*, we mean the converse of radiant heat; that is, the reflection or resilience of heat against the solar supply, causing an accumulation on the enlightened surface of the globe, and the lower strata of the atmosphere, between sun-rise and sun-set; for any meridian is warmer then, than between sun-set and sun-rise. The reason is, that as the earth intercepts the caloric *in transitu* from the sun, it accumulates sensibly on every meridian from sun-rise till about two P. M., because the amount intercepted is more than the demand for evaporation, (which alone prevents the temperature from rising too rapidly;) and the temperature decreases sensibly from thence till sun-set, by the effects of evaporation only; for the supply is diminishing by increasing obliquity, while the demand of evaporation is not reduced in equal ratio. At sun-set, each meridian comes in turn within the influence of the cone of transmission, and the reflected heat then becomes radiant heat, as before defined.

Having defined the meaning of radiant and reflected heat, we shall give the sense in which we use *divergent heat*. The word *divergent* is strictly synonymous with radiant; but we restrict its meaning to radiation or divergence in a geographical plane. From this, it will be easy to conceive the nature of the calorific or magnetic flow from the zone of neo-magnetic intensity, and a change of principle will be observed. For, whereas, the caloric of the magnetic equator radiates and converges from a circle toward two points, but loses its terrestrial polarity on reaching the circle of magnetic confluence, or line of greatest cold, along which it traverses easterly and westerly toward the magnetic poles; the caloric of this zone, emanating from the waters supplied by the equatorial currents, radiates and diverges from a centre toward the same line, and then converges with the deflected equatorial flow toward the same poles. At the equator, the effort is to raise the temperature of the moisture to that of the atmosphere; in this zone, the reverse.

From all this, we must expect some curious and contradictory phenomena, did we not know the cause. It is fair to suppose that the horizontal and vertical needles, supposing the calorific flow to be the cause of their direction, when placed at the centre of neo-magnetic intensity or warm pole, (contrary to the effect at the source of the equatorial flow) would be useless as at the magnetic pole: for, as the central flow of caloric diverges on all sides, the needle would be equally affected in all directions, and indicate no point of the compass. On proceeding from either cold pole toward the warm pole, the horizontal needle would traverse again, with its north end pointing south; and this is actually the case; and the vertical needle would become gradually horizontal on approaching the centre of neo-magnetic intensity.

We are not yet acquainted with the disposition of land and water in the southern hemisphere; but analogical reasoning will convince us that similar or modified phenomena will take place there also.

The natural positions of the points of greatest cold, or the magnetic poles, are in the centres of the arctic portions of the continents; but they are liable to be driven from their positions by adventitious circumstances. Should the ice, in its descent from the polar seas, lodge itself east, or west, or north, of either continent, or block up the Greenland sea, instead of passing off into the southern seas, and melting there, it is plain there is an increase of continental surface;

for the ice prevents the transmission of warmth from the water beneath; and, consequently, the points of greatest cold are removed east, or west, or north, accordingly. This lodgment will take place, when the ice breaks up in a remarkably quiet spring, and comes down in larger unbroken masses than usual, settling along the northern shores of the continents; and a tranquil season ensuing, the succeeding winter strengthens the whole, and it increases in future winters, bringing the poles in the same direction.

This state of things continues till its thickness is such as to prevent the equal, external, and internal transmission of caloric, on rather sudden changes of temperature; when the unequal contraction of the outer shell upon the strong inner nucleus, causes it to rend in a thousand directions, to restore the equilibrium of mechanical pressure; and when once the work of destruction is begun, its own vibrations continue it, and the gathered treasures of an hundred years are scattered to the winds and waves. Storms, also, and tempests, in the middle latitudes at the equinox, raising powerful temporary swells, the hydrostatic pressure of which is communicated north, as well as in other directions, acting on the principle of the water ram, prevent the centre of the polar ocean from being ever entirely frozen over, and break the icy barrier when it has extended itself too far north, and thus play their part in its destruction. It may indeed be said, that its grasp at universal empire is the cause of its own ruin; for, though old ocean may permit its undisturbed increase for a time, yet the period will arrive when his pent-up currents will turn upon the usurper, drive him from his encroachments, and resume his wrested rights. Thus, empires rise and fall by usurpation, and, in animal life, growth carries in itself the principles of decay. The separated masses float toward the lower latitudes, and the points of greatest cold retreat again, in proportion to their proper continental situations.

But, besides this arbitrary shifting of the magnetic poles, they have also a periodical solstitial motion, northerly and southerly, arising from the path of the sun in the ecliptic. The American pole will shift north-easterly from the winter to the summer solstice, in order to retain its central continental situation, owing to the greater amount of land to the north-east; and, consequently, return south-westerly, from the summer to the winter solstice. They have also periodical diurnal motions; but we shall reserve the explanation of these motions, till we come to treat of the diurnal and solstitial variations of the needle.

From this it is evident, that the magnetic poles cannot in their nature be stationary, nor rotatory round the terrestrial poles, nor regular in their progress east or west. Yet, so long as there is no material change in the situation of the ice, the poles will be stationary, as far as regards an easterly or westerly movement from that cause.

Having considered the nature of the magnetic equator, and magnetic poles, and divided the globe magnetically into eleven zones, we shall now enter on the subject of the variation.

In order that there may be no misunderstanding, we beg to remind our readers of the meaning of the word *flow;* a term of necessarily frequent recurrence in treating of the variation, and other magnetic phenomena. By it, we mean to express the passage of caloric, as a distinct element, from the media in which it is diffused, moving like a current of air; in other words, *flow* bears the same relation to *caloric,* that *wind* does to *air.* The word prefixed, shows the quarter from whence it comes, as in speaking of the winds: the words *northerly* and *southerly,* prefixed to equatorial, denote the hemisphere; thus, northerly equatorial flow, denotes the equatorial flow of the northern hemisphere, &c., which is determined by the magnetic, not by the terrestrial equator. We shall consider the flows of caloric, as affecting the needle separately, for the sake of perspicuity, and the composition of their forces upon it, as producing its direction:

but in reality they resolve their forces on themselves, and the resulting direction of the combined flows is what governs the needle.

In looking at the lines of no variation, we are puzzled by the seemingly contradictory courses which they take, both with respect to preconceived ideas, and with respect to each other. On a superficial view, it should appear, according to the theory, (viz: that the passage of caloric to the points of greatest cold was the cause of polarity,) that the needle should always look to the points of greatest cold; and that, consequently, the meridians of the magnetic poles, in their respective hemispheres, should form lines of no variation; because the needle would, any where on those lines, point to the terrestrial poles, by looking through the magnetic. But this is not the case; and, therefore, there is some reason, which we shall endeavor to explain.

If we follow the track of the lines of no variation, as they actually exist, we cannot but conclude that their course is chiefly dependent on the disposition of land and water. This is remarkably evident by inspection of the American line, which may be said to take the general sweep of the continent; while that of Asia appears far more intricate: nevertheless, a good reason may be assigned for this.

The equatorial currents of caloric, flowing toward the American pole, over the continent, are uninfluenced in any material degree, in their direction by the American chains of mountains; for the principal ranges, the Andes, the Cordilleras, the Rocky mountains, and the Allegany, take the same general sweep as the main body of the continent, and equatorial flow of caloric. In Asia, on the contrary, the long ranges of the Altay, the Mus-Tag, the China, the Thibet, and the Himmaleh mountains, (in degree) run east and west right across the general equatorial flow of caloric, and consequently affect the line of its direction over a large portion of that vast continent. Although the ranges on the west of the old continent, as the Mountains of the Moon, the Carpathian, and the Spanish, run in much the same direction, they have not the same effect, because that part of the old continent obeying another pole, the American, to the north-west, the general northerly equatorial flow of those parts takes a westerly course; that is, the same general direction as the mountains.

We would here make a preliminary remark, on the nature of magnetic variation. As the cold or magnetic pole, is situated south of the terrestrial pole, a needle pointing to it, when east of its meridian, will have a westerly variation, and when to the west, an easterly variation, from the terrestrial or north pole. When it is on the meridian of the magnetic pole, and *points to it*, there will be no variation, because it looks through it to the terrestrial or north pole: yet this can rarely be the case, owing to local diverting causes.

But it will be asked, why does the needle leave the magnetic pole for the terrestrial, when it is situated on the line laid down as the American line of no variation; while, on the meridian, which looks to the terrestrial pole through the magnetic, except in one point, it always shows a variation? And why is the north end of this line to the west of Hudson's Bay on the continent, and continued south-easterly through the great lakes, passing on to the north of Washington, then leaving the continent a little north of Cape Hatteras, to stretch across the Atlantic ocean, to the east of the West Indies, touching Cape St. Roque, then stretching across the South Atlantic, to cut the magnetic equator about lat. S. 12°, long. W. 32°? We shall endeavor to explain these facts, and show that they are a main support to the theory. We shall commence with that part of this line included between Cape Hatteras, and Cape St. Roque.

The needle on this line would follow the general flow of equatorial caloric to the pole, which would be a little west of north; as it is situated east of the meridian of 92° W., the longitude of the magnetic pole, and indicate a variation accordingly from the terrestrial pole, or true north point in the heavens, were there no disturbing cause. But we must recollect that there is a flow from the west to the east, or from the land to the ocean, tending to equalize their temperatures, and supply the great demand of marine evaporation; and this, acting on the needle, diverts it toward the east from its natural course, and in certain *points* will turn it due north; which points being joined, form a line where the needle points due north, and is therefore called a *line of no variation*.

To prove this, we shall make some suppositions with respect to temperatures, the incorrectness of which will not invalidate the principle, though it may the actual result.

Let us suppose the temperature of the cold pole to be 32°, and that of the atmosphere over the ocean, in lat. 30° N., lon. 70° W., (a spot at or near which the needle points due north) to be 80°; then the difference of local and polar temperature, or the numeral 48, expresses the momentum of the calorific flow from thence to the cold pole, moving a little to the west of north. Let the temperature of the eastern coast of America, in the same latitude, be 86°; the difference of temperature between this point and that of no variation, is 6°, which numeral expresses the momentum of a westerly flow, acting at right angles (theoretically) on the equatorial flow, from the point of no variation, diverting it easterly. But the momentum of the diverting flow (6) is one-eighth of that of the general flow (48;) wherefore, the latter is diverted one-ninth of a right angle, or 10°, from its natural course to the cold pole, easterly toward the terrestrial. But this is not the true result; for this angle is reduced, in consequence of the volume of the westerly flow being already in motion toward the north, so that its momentum is really exerted in a north-easterly direction. The result of the composition of the forces, is a deflection toward the terrestrial pole. The same reasoning applies from Cape Hatteras to Cape St. Roque.

The reason why the line of no variation particularly intersects the continental line of the eastern coast at Cape Hatteras, arises from the following causes: In advancing from the equator, the continental atmosphere decreases in temperature in a much faster ratio than the marine, causing the latter to exceed the former in the higher latitudes; so that there is a westerly flow from the land to the ocean, in the low latitudes; and an easterly flow from the ocean to the land, in the high latitudes; while in certain middle latitudes, the flow will fluctuate east and west, in winter and summer respectively. As the whole east coast of North America is east of the meridian of the cold, or magnetic pole, a needle any where on this coast, following the equatorial flow to the cold pole, should note a westerly variation from the terrestrial pole. Under these conditions, it is evident there cannot be a point of no variation on the coast in the higher latitudes; because, as the equatorial flow there would note a westerly variation, the oceanic flow to the continent would only increase it. It must therefore fall where a westerly flow prevails from the continent to the ocean. This could not take place in very low latitudes; for as the coast approaches the meridian of the cold pole, by trending in a south-west direction, the equatorial flow to the cold pole would note a continually diminishing westerly variation in its direction, with the progressive decrease of latitude on the coast; and the continental flow to the ocean, increasing with the increase of terrestrial temperature in proceeding south, would not only correct the small aberration of the equatorial flow from terrestrial polarity, but divert it, and consequently also the needle far to the east of the terrestrial pole, as is absolutely the case in these parts.

The point of no variation must therefore fall on the coast, somewhere near the northerly prevalence of the westerly continental flow, and this must evidently happen somewhere about Cape Hatteras.

South of this cape, the line of no variation should pass (as it does) east of the continent over the ocean, increasing its distance from the land in its southerly progress; for the oceanic equatorial flow in the vicinity of the continent continuing much the same, while the continental westerly flow increases with the increase of continental temperature or absolute volume of caloric, in proceeding south, this will cause the diverting power of the latter flow upon the former to be increased; and, as the angle of variation, denoted by the equatorial flow alone near the shore, diminishes as the coast approaches the meridian of the magnetic pole, by trending south-westerly, a needle there, obeying the two flows, would note an easterly variation. But, on proceeding east from the coast, the power of the westerly flow would diminish; and diverting the equatorial flow less from its natural course, the needle would measure a continually diminishing easterly variation, in receding from the coast, till at length it noted no variation at all. The distance of these points from the coast would gradually increase, in proceeding south, from the point of intersection at Cape Hatteras, because of the gradually increasing power of the westerly flow to the ocean, with the gradual increase of continental temperature: it would, also, depend on the extent, as well as on the temperature, of the southern sections of the continent.

From hence, it is evident, that north of Cape Hatteras, the line of no variation must pass inland, as it does; the reason of its exact track we shall give in detail; as also why it approaches Cape St. Roque.

At any spot, where this line crosses the great lakes, if the needle looked to the magnetic pole, it would note a westerly variation; but this is obviated in the following manner: In these latitudes, the temperature of the atmosphere over the fresh waters is below that of the atmosphere over the land; consequently, there are flows from the land to these vast inland seas from all points. The northerly flow causes only a retardation of the equatorial or general magnetic flow, without altering its course; the southerly, causes only an acceleration of the equatorial flow, without altering its course; but the easterly and westerly flows, acting at right angles on the equatorial, affect its direction in proportion to their forces. Now, the range of land west of the lakes, bounded by the Rocky mountains, is far greater than the range of land east of them; and, therefore, the volume of the westerly flow, toward the lakes, is far greater than that of the easterly flow toward the same points. As the equatorial flow from Lake Michigan, or Lake Superior, carries the needle north with a small westerly variation, the easterly flow alone, from the Canadas, would increase this variation, were it not that the superior westerly flow carries it east, and in a certain line points it due north. Hence, while the cold pole continues west of the meridian of 75° W., the continental points, or line of no variation, in the magnetic or calorific currents, can never fall east of the lakes; for, as the equatorial flow would note a westerly variation, the easterly flow, toward the lakes, would only increase it.

On reaching longitude 92° or 93° W., (the meridian of the pole) about the latitude of 51° N., the same latitude as the south end of Hudson's Bay, the equatorial flow is uninfluenced, or equally influenced, on all sides; and, flowing north, along the meridian, at that point, toward Hudson's Bay, carries with it the needle, which points due north, looking through the magnetic to the terrestrial pole.

In its course from this last mentioned point, north-westerly, to lat. 60°, long. 100°, a needle situated on it, and following the equatorial flow toward the magnetic pole, would point some degrees east of the terrestrial pole; but the atmospheric temperature over the easterly salt waters of these high latitudes, being warmer than that of the land, and their flow affecting the needle on its eastern side, carries it westerly, and in a certain line, points it to the terrestrial pole.

The reason why it touches Cape St. Roque, instead of continuing its course over the ocean, away from the land, is owing to the following causes: The great western stream, commencing on the west coast of America, acquires a high temperature, from its long tropical course; being arrested in its career by the east coast of Africa, it is deflected to the south; and after doubling Cape Lagullus, where it assumes the name of the Lagullus stream, it takes a north-west course through the South Atlantic, causing an unnatural temperature in that ocean. As the equatorial flow alone at the Cape, close in land, would carry the needle west of north, (being situated east of the polar meridian,) the easterly flow from the Lagullus stream would increase the variation; but the strong westerly flow from the continent, (the temperature of its atmosphere being always higher than that of the ocean,) counteracts the effects of the stream, and causes the needle to point due north. It is plain, that as the equatorial flow at the Cape notes a small westerly variation, the westerly flow alone, close in land, would carry the needle east of north; and thus, without the effects of the Lagullus stream, the line of no variation would not here approach the continent.

After leaving Cape St. Roque, this stream tracks along the north coast of South America, passing through the Caribbean sea, and entering the Gulf of Mexico by the south of Cuba. In this part of its course, it has no diverting effect on the equatorial flow; for being north of the continent, its flow unites with the equatorial flow. South of the Cape, the line of no variation leaves the land and the stream, taking a south-easterly course between the two, where their respective westerly and easterly flows act with such a proportional intensity upon the northerly and southerly equatorial flows, as to divert them from the magnetic toward the terrestrial poles.

The variation, east of this line of no variation, becomes westerly, and west of it, easterly; which appears contradictory, unless we know the cause. It must be observed, however, that the whole of this line from about lat. 50° N., to the magnetic equator, is east of the meridian of the cold pole; and, by consequence, the natural direction of the equatorial flow, from any point in the line toward the cold pole, indicates a westerly variation from terrestrial polarity, as before observed: but we have already shown, that a westerly flow, diverting the equatorial flow from the cold pole toward the east, caused the production of the line of no variation in its present path. Now, a flow of caloric is stronger at its source than at an increase of distance from that source. As, therefore, the origin of the deflecting flow is to the west of the line of no variation, it follows, that nearer its source than the line of no variation, the increasing force of the westerly flow will deflect the equatorial flow (which also measures a smaller variation, in consequence of diminished longitudinal distance from the meridian of the cold pole,) to the east of north, thus denoting easterly variation. East of the line of no variation, the diminishing force of the westerly flow will deflect the equatorial flow, (now measuring a larger angle of variation, in consequence of the increase of its longitudinal distance from the meridian of the cold pole) to the east of its natural direction; but leaving a westerly variation from terrestrial polarity; which westerly variation increases with the increase of longitude, to the east of the line of no variation; and a number of points, denoting the same easterly or westerly variation, being joined, form what are called the lines of easterly and westerly variation, and are found on the *reciprocal* sides of this line of no variation.

This principle accounts for the apparently anomalous fact, that the meridian of the cold pole is not a line of no variation, as superficial reasoning, on this theory, would lead us to conclude: for, though the tendency is to point north, through the magnetic pole, yet the different forces of an easterly or westerly flow of caloric, or the prevalence of either alone, owing to local causes, affecting the equatorial flow, produces a deviation from the geographic meridian, and, consequently, an easterly or westerly variation. The same principle will account for local points of no variation, should there be such, and difference of variation at the same place, in different seasons, without recourse to the supposition of magnetic iron ore in the vicinity.

From this, it is evident, that the needle as rarely points to the magnetic as to the terrestrial pole, and consequently, there are, as a philosophical curiosity, lines of no variation from magnetic polarity, as well as lines of no variation from terrestrial polarity.

Yet it cannot be denied, that local attraction does sometimes affect the needle. Thus, on the top of Mount Exmouth, in New Holland, the north pole of the needle points magnetically south, and gradually returns to the north, on descending the mount, and leaving its neighborhood. This curious phenomenon was observed by Mr. Oxley, in the course of some government surveys. There are also many other points, on that extensive island, where the needle is affected materially, as at Loadstone Hill. It is, most probably, owing to a vein of magnetic iron ore, lying in or near the magnetic meridian of the place. Thus, a small compass, placed over a large one, will point with its north pole to the south.

The line of no variation will not always be found in the same situation, but must continually shift its position. The causes of this will be, the path of the sun in the ecliptic, occasioning different relative temperatures, in different seasons, between the atmospheres of the land and water; causing it to move easterly or westerly, as the proportional forces of easterly or westerly flows are shifted longitudinally to other points on the equatorial flow. The diminishing obliquity of the ecliptic, and the nutation of the earth's axis, affect it in some slight degree; but these are annually inappreciable. Aerial and marine currents will also affect it; and the latter more permanently, as they are not quite so changeable. The alteration of the outline of the coast, also, produced by geological changes in the revolution of ages, will alter the relation of land and water, and, by consequence, the position and form of the line of no variation. The continental part of this line will be materially changed, perhaps, when the great lakes and Hudson's Bay are frozen over, from its position during summer; also, by the solstitial change of the magnetic poles.

It appears reasonable to suppose, that whenever the line of no variation shifts, whether easterly or westerly, it will change its form also nearly to that of the line of variation whose place it occupies; and for this reason: being in the same latitude and longitude, it is affected by the same local causes; and, as the direction of the equatorial flow only is altered, it will take very near the same direction as the pre-occupying line of variation.

The Asiatic line of no variation is far more complex, but the same remarks apply to many parts of it, and it even confirms the truth of our reasoning. The fact is, the direction of the mountains, and the absence of land at the equator, with a great breadth of land near the tropics, and the two extensive peninsulas of Hindoostan and Farther India, extending within the tropics, together with the larger islands east of the continent, and the intervening seas, exercise a material influence over the direction of the equatorial flow.

That part of the line, contained between the parallels of 48° and 71° N., and the meridians of 97° and 120° E., is occasioned by the same causes as the American line; viz: a counteracting force upon the equatorial flow, produced by general causes. Siberia, being for the most part a level country, presents but few diverting causes; and, therefore, the equatorial flow, over the meridian of the pole, would naturally form the line of no variation. The well known fact, however, (which we shall explain hereafter,) that the eastern coast of each continent is colder than the western, causes a flow toward the east, which diverts the equatorial flow in that direction, and causes the line of no variation to fall to the east of lon. 97° E., the meridian of the pole. Lake Baikal is almost the only cause of diversion; and, as the line of no variation falls west of it, the westerly flow toward that vast sheet of water, causes the southern part of the line to approach it, and fall further to the east than the rest of the line. East of this line the variation is west, and west of it east, as with the American line, and for the same reasons. This is not a general line, which is owing to the easterly and westerly set of the long range of the Altay, running right across the general equatorial flow, causing a mechanical diversion of the current.

In consequence of there being two cold poles in the northern hemisphere; and that the passage of caloric is the cause of the affection of the needle; and that the needle, between the poles, points to the one or the other, according as the flow is strongest east or west; it is plain, there will be a certain line between the two poles, where it will point to the terrestrial pole. From this it is evident, there must be *four* lines of no variation in the northern hemisphere.

Two of these four lines of no variation, the American and Asiatic lines just described, we have shown to arise from the modified equatorial flow toward *one* pole only, (though a different pole for each line) and that consequently the lines of westerly variation must be on the east, and those of easterly variation on the west of each of these lines. We shall call these the *true lines of no variation.* The other two (situated east and west of the true Asiatic line) we shall show to be produced by the local equality of power of two poles, or rather of the equal directive power of two flows, diverging east and west from the spot of observation, toward *two* poles. These lines form, as it were, the boundaries of the empire of each pole. In order to distinguish them from the other two lines of no variation, we shall call them the *virtual lines of no variation;* and shall show that their lines of easterly variation must fall on the east, and those of westerly variation on the west of each of them, (as is actually the case) on this supposition.

It is plain, that if London be situated on a meridian midway between those of the two magnetic poles; and if the two poles be of the same intensity (or cold); the needle at that city will point due north. For, by reason of the equality of cold at the two poles, whatever portion of caloric exists about London, it will be equally influenced by them: and equal volumes, flowing east and west to them, will give rise to two diverging flows from thence, the remaining volume continuing to the north in the line of division between them, being in effect a calorific line of no variation. This line, then, is the line of the equality or balance of power of the two poles. If, in the course of time, the Asiatic pole becomes weaker, owing to the diminution of its arctic surface, of the existing volume of atmospheric caloric at London, (still situated midway between the two poles) a larger portion is transmitted to the American pole, and a smaller portion to the Asiatic than before; wherefore, a point situated nearer to the Asiatic pole, in proportion to the diminution of its power, will be the point where the influence of the two poles will be equally felt, and consequently the point where the equality of calorific divergence will take place, causing the calorific line of no variation to fall in this case east of London, and the needle at London to vary westerly. An increase of power in the Asiatic pole (or what is the same thing, a diminution of that of the American) would cause the calorific line of no variation to pass west of London, and the needle at London to vary easterly.

Pursuing the principle of a certain balance of power, we joined the American and Asiatic poles, by a right line, on a chart, and divided this line into two, by taking a point one third its length from the Asiatic pole, as the point of balance of the powers, (considering the American pole to be twice as cold as the Asiatic) the distances being inversely as the powers. Upon this line, as a base, we raised a number of triangles, one for every 10° of latitude, toward the magnetic equator, whose sides toward the American pole were twice as long as those toward the Asiatic. We then joined their apexes with the point we took in the base; and, to our surprise, never having seen a variation chart, on comparing it with one a few days after, found we had nearly brought out the line which M. Hansteen lays down as the line of 5° west variation.

It passed south-easterly, east of Lapland, through the heart of Russia in Europe, through the east of the Caspian Sea, by the east of the Straits of Ormus, just cutting east of Cape Rosalgat, in Arabia. This was the result of the balance of powers only; but had we then known the causes of the actual paths of the true lines of no variation, as before explained, and allowed a curve through the east of Lapland, by reason of the warm flow from the White Sea toward the west; and another through the Caspian Sea, by reason of the south-west flow toward it from the sands of Arabia, it would have coincided nearly exactly with the line of 5° west variation, as laid down by M. Hansteen: and had we assumed the powers of the two poles as 5 to 13, (instead of as 1 to 2) as will be seen hereafter, we should have projected the actual virtual line of no variation.

We before showed, that when the line of no variation travelled east or west, it would most probably not deviate far from the track of the line of variation which it displaced. If this be the case, the virtual line of no variation, at present nearly coinciding with the meridian of 45° E., as far south as lat. 51° N., lon. 60° E., in proceeding westerly would expand its curve, and follow the direction of the present line of 5° west variation; or, in retreating east from that line to its present situation, would contract its curve to its present form.

In the first case it is evident it would not join the rest of the Asiatic line, but would vanish at the magnetic equator; unless it continued south as a line of no variation, toward the south magnetic pole: but this is improbable. We therefore think this line does not join the line of no variation, situated between the meridians of 90° and 120° E., and the parallels of 71° and 47° N., as M. Hansteen lays down; but that it vanishes somewhere, perhaps south of the Ural mountains, toward the Belur Tag; or if it be joined, the line which joins it is dependent on local causes.

We regard the line of no variation on the eastern coast of Asia, north of the parallel of 54°, in the same light, considering it as the result of an equal intensity of the directive forces on the west of the American pole. We are as yet unacquainted with the interior of the Chinese empire, and consequently the state of the variation there must be but very imperfectly known.

This view of the virtual lines of no variation is borne out by their relative distances from the Asiatic true line of no variation, as compared with their distances from the American, and the comparative intensities of the two poles; an allowance being made for the eastern line, because of the greater coldness of the eastern coast, which causes a proportional westerly flow of caloric from the ocean to the eastern coast, and thus causes the virtual line to approach nearer the true line.

The ratio of the number of degrees of longitude included between these two virtual lines of no variation, to the east and west of each, may be considered as indicating the relative intensity of the two poles. The number of degrees included between the east of the European, and the west of the Asiatic virtual lines, is about 100; this is the range of the Asiatic pole, and includes the Asiatic true line of no variation; and the number included between the west of the European and the east of the Asiatic virtual lines, is consequently about 260; this is the range of the American pole, and includes the American true line. Therefore the power of the Asiatic pole is to the American as 5 to 13. Now the distance of the European virtual line of no variation from the Asiatic and American true lines respectively, calculated on the parallel of 60°, is actually in this ratio; which is strongly confirmatory of the hypothesis of its origin. It is true the distances of the Asiatic virtual line are not in the same ratio, but we have given the reason in the preceding section. From hence we conclude that the present continental surface of arctic Asia is to that of arctic America as 5 to 13.

That this is the real cause of the European virtual line of no variation west of the Asiatic true line, and that it is not produced by a third centre of greatest cold, as imagined by Dr. Metcalf, is evident for several reasons. About the year 1406, when the ice blocked up the Greenland sea, there can be no doubt, but that the north of Europe and Asia suffered in like manner, because they present a better coast to detain the ice, than the islands of Spitzbergen and Iceland; besides, the ice to the north of the continent could not then escape as usual through the Greenland sea. The variation at that time in England must have been easterly, as it was from the year 1492, when it was first observed, till 1657, when the line of no variation (the virtual line we are now speaking of) passed over London, and the variation instantly became westerly, and has been so ever since, as this line has proceeded easterly.

Now, if this were a line of no variation, obeying a separate pole, distinct from the Asiatic and American, its motion must be owing to its pole retreating in the same direction. In this case it is evident, that while London was east of the line of no variation, the variation should have been westerly; and, as soon as the line moved east of London, with its pole, the needle there which obeyed it, should have followed and noted an easterly variation.

But the contrary is the fact; for while London was east of the line of no variation, the variation was east, decreasing as it approached, till it passed over that city in 1657, *when it amounted to nothing; and no sooner was London* *west of the line, by its easterly retreat, than the needle there indicated a westerly variation.* This clearly shows that the line now under consideration is not the result of a distinct pole.

If we consider it as the boundary line of the influence of the two poles and of the balance of their powers, the reversed conditions of the accompanying lines of variation follows as a corollary. At the time the line was over London, there was no variation, because the forces to turn the needle from the geographic meridian east or west, toward the American or Asiatic pole, were equal. As soon as London, by the easterly retreat of the line of no variation, was west of the balance of power, that is, in the influence of the western or American pole, in turning to it, the needle would necessarily note a westerly variation; and when to the east of it, being in the influence of the eastern or Asiatic pole, in turning to it, the needle would note an easterly variation.

This line of no variation has moved east from the island of Ferro, one of the Canaries, to the meridian of 45° E., or 63° of longitude, which has been occasioned by the decreasing power of the Asiatic pole, as will be shown when we come to treat of the variation of the variation.

We should remember that the variation east of the *true* line of no variation is westerly, and west of it easterly; while east of the *virtual* line of no variation, it is easterly, and west of it westerly. Connect all this reasoning with the result which we obtained upon the chart, and the result is irresistible, *that it arises from an equality of the directive powers of two flows diverging toward the two poles, from the same place.* In short, it is incontrovertible, that the boundary of easterly and westerly variation must be a line of no variation at all. We may also add, that if there were *three* centres of greatest cold, or magnetic poles, governing the needle, there must then be six lines of no variation: one true line belonging to each pole; and one virtual line between every two true lines, being the boundary lines of the empires of each pole.

The lines of variation, like those of no variation, are formed in two ways, and may be divided into two classes, bearing the names of the lines of no variation, from which they take their origin.

The *true lines of variation* are known, by being on the reciprocal sides of the true lines of no variation; those of easterly variation on the west, and those of westerly variation on the east. They are formed by the reciprocal increase and decrease of that particular intensity of the easterly or westerly flows which diverted the equatorial flow of caloric from its course (to the cold pole) toward the terrestrial. It is evident, that east of the true line of no variation, the diminished force of the deflecting westerly flow toward the east, owing to increase of longitudinal distance from the meridian of the cold pole, will cause the increased easterly flow toward the west, owing to diminished distance from the source, (the momentum of the equatorial flow being the same) to divert the needle more to the west, and thus cause a westerly variation; and *vice versa* west of the line.

The *virtual lines of variation* are known, by being situated on the corresponding sides of the virtual lines of no variation; those of easterly variation on the east, and those of westerly variation on the west. The reason of this is, that in advancing west of the virtual line of no variation, (which is formed by a balance of power) the power of the western pole increases, while that of the eastern decreases; that is, the flow from any given place toward the western pole is greater than that toward the eastern pole, and carries the needle westerly; and *vice versa* on the east of the virtual line.

The exact tract of each species is dependent on local causes, as in the lines of no variation.

The nature of these four lines of no variation, and consequently of the lines of variation resulting from them, may be prettily illustrated by the following experiments.

To exemplify the nature of the true lines of variation and no variation, draw a line for a meridian, and let its termination be the north terrestial pole. On this line, at some distance from the pole, lay a magnet, to represent the magnetic pole, and place an unmagnetized needle, suspended as a compass, on the line south of it: it will turn, and coinciding with the meridian, point to the terrestial pole, by looking through the magnetic. This is the true line of no variation. Bring the needle east of the meridian, and in looking to the magnetic pole it will note a westerly variation from the terrestial: bring it to the west, and it will note an easterly variation. This shows that the true lines of no variation, dependent on the action of one pole, must have their lines of easterly and westerly variation on their reciprocal sides.

In order to exemplify the virtual lines of variation and no variation, lay the needle in the terrestrial meridian and place the north pole of a magnet that will sustain one ounce to the east of it, to represent the Asiatic pole: the needle will leave the meridian and turn to it, noting an easterly variation. Take away this magnet; bring the needle to the meridian, and represent the American pole by placing the north pole of another, that will sustain two ounces to the west of it, and at such an increased distance, that its power at the meridian may be equal to that of the former magnet: the needle will leave the meridian, and, turning to it, note a westerly variation, equal to its former easterly variation. Now if we replace the Asiatic pole, the needle will leave the American, and, coinciding with the meridian, will point due north: for though twice as powerful, the American pole is more distant, and, therefore, *virtually* equal to the Asatic: this is the *virtual* line of no variation, or the line of the equality of power of two poles.

Move the Asiatic pole a little east, and the needle is *vir-*

tually nearer the American; because its influence remaining the same, while that of Asia is virtually diminished in some ratio with its increased distance, the former has greater power over it. It therefore turns to the American pole, and notes a westerly variation, which increases with every easterly remove of the Asiatic pole. Here, it is evident, that the balance of power, or virtual line of no variation, produced by the action of both poles, is removed east of its former meridian, and that the variation west of that line is west. Bring the same pole west of its first position, and being nearer the needle, its power is *virtually* greater than that of the American pole, causing the needle to note an easterly variation from the meridian. Here, it is evident, that the balance of power is removed west of the meridian, carrying with it the virtual line of no variation, and that the variation east of that line is east.

This shows that the virtual line of no variation, produced by the easterly and westerly action of two poles, must have its lines of easterly and westerly variation on its corresponding sides.

The dip increases with the latitude, reckoning from the magnetic equator: the variation is not dependent upon latitude, but upon longitude, reckoning from the line of no variation as from a meridian. Therefore, the lines of no variation are the first magnetic meridians of the ranges they govern; and every degree of east or west variation to their extreme range, may be reckoned so many degrees of magnetic longitude; and as the true and virtual lines of equal variation necessarily join each other, the former may be denominated *reciprocal*, the latter *direct* magnetic longitude. These lines will be found to continue into the zone of neo-magnetic intensity. The point of junction determines the extent of increase of the variation from each line of no variation, as before alluded to. As the virtual and true lines of variation are found to join in the middle and lower latitudes, it is not improbable they may join also in the northern regions; as likewise the European virtual line and the American true line of no variation.

The continuation of the Asiatic virtual line of no variation, from the eastern Altay through the continent, to the Bay of Bengal, is mainly dependent on the mechanical diversion of the equatorial flow, caused by the arrangement of the mountains throughout that extensive tract: for as the ridges set across the equatorial flow, the currents of caloric impinging against their sides will be diverted along the intervening valleys, as affording less resistance, and being a readier way of arriving at their final destination, (the cold or magnetic pole,) than by passing through the ranges themselves. The currents of caloric are governed by the same laws as those of fluids, of gases, or of light.

That part of the line between the parallels of 54° and 40° N., from the river Amour to the Yellow Sea is thus produced. The equatorial flow from any point in that line being east of the meridian of the magnetic pole, in pointing to it, would note a westerly variation: but the north-easterly set of the Tartarian mountains and of the coasting range, diverts it from its natural course, causing it to proceed easterly along the extensive valley between them, and in a certain line carries the needle due north. Proceeding south along the line, to its intersection with the meridian of the pole, (long. 100° E.,) the equatorial flow should note, as before, a westerly variation: but being diverted easterly by the same causes, and also by the flow toward the Yellow Sea, in order to equalize the temperatures of the marine and terrestrial atmospheres, in a certain line it will course due north, and point the needle in the same direction. West of the meridian of 100° E., the equatorial flow would naturally note an easterly variation, but this is counteracted by the north-westerly set of the mountains and valleys of Thibet; causing it to take their direction; and in a certain line arising from the composition of certain intensities of the equatorial tendency and its mechanical diversion, it traverses due north and carries the needle with it.

This line is continued through the Bay of Bengal and south of the magnetic equator. That part passing through the Bay of Bengal, may be supposed to be produced by the following causes: On the west of the bay, the equatorial flow to and over the continent becomes north-west, although situated west of the meridian of the magnetic pole, being diverted by the lofty range of the Himmaleh mountains, which run in that direction, and confine it between themselves and the coast: at the same time, the equatorial flow on the other side of the bay flows more nearly in its natural direction toward the cold pole, by reason of the northerly range coasting Further India, especially that part of the flow toward the middle of the bay. It is evident, therefore, there will be a line, somewhere between the two, where the flow will be due north, and direct the needle accordingly.

That part of this line south of the magnetic equator, is caused thus: The southerly equatorial flow being directed (as will be shown hereafter,) to a cold pole in the antarctic circle, somewhere on or near the meridian of 10° W., should note a westerly variation; but being pent up east and west by land, it is constrained for a limited course, about the middle of the ocean to proceed due south. We think that this line is continued too far south; it certainly is for the present state of the variation in those seas.

With respect to the line of no variation to the east of Luzon and Borneo, we conceive that part of it north of the magnetic equator to be occasioned by the divergence of the local calorific currents toward the two northern poles, as was before explained, for the production of the European and Asiatic virtual lines of no variation. We think it would join the virtual line north of the latitude of 54°, were it not for the local causes which we have noticed as producing the continuation of this line along the coast to the Yellow Sea.

The line of no variation from Formosa to Sumatra, following the shores of the China sea, is owing to the confluence of the easterly and westerly variations of the above mentioned lines respectively, which, in a certain line, will inevitably point the needle due north. It is in fact a true line of no variation, its variation lines being on reciprocal sides.

From the circumstance of there being only two general lines of no variation in the southern hemisphere, the American, which is a true line, and that of New Holland, which is a virtual line, we conclude that there is but one pole in that hemisphere, situated somewhere about the meridian of 10° west. In this case there can be but two lines in which the calorific currents of the southern hemisphere would denote no variation, one of which would be a true and the other a virtual line: the former caused by the confluence, and the latter by the divergence, of one easterly and one westerly flow, in their passage toward the pole.

If, for the sake of argument, we suppose this pole to be situated in lat. 72° S., lon. 10° W., then, supposing the earth even and uniform in substance, and that there are no local diverting causes, there would be a calorific flow due south along its meridian; that is, a calorific line of no variation. For, all places north of the parallel of the pole, when west of its meridian, would transmit their caloric to it in an easterly direction; and when east of its meridian, in a westerly direction. The confluence of the two forces would form a true line of no variation; inasmuch as when east of it, the needle, being in the influence of the easterly flow, would note a westerly variation, and when to the west, being in the influence of the westerly flow, an easterly variation.

Now, the opposite meridian of 170° E. is the line from whence the easterly and westerly flows would, in this case, take their origin, and diverge from each other. This would also be a line of no variation; for, east of the meridian, the needle would obey the easterly flow, and consequently note an easterly variation from the meridian, i. e. from the terrestrial pole; and west of the meridian would obey the westerly flow, and note a westerly variation: but as in the act of changing the variation from east to west, or *vice versa*, the needle would point due north, there must be a line where it points due north, or a line of no variation coinciding with the meridian of 170° E.; and as the conditions of this line are easterly variation to the east of it, and westerly variation to the west of it, it is a virtual line of no variation.

But as the earth is not even and uniform, local circumstances cause these lines of no variation to deviate from the meridians, as before explained. The virtual line is also nearer to the east of the true line, than to the west of it, which is owing to the greater extent of land to the east: for this causes a greater body of redundant caloric to the east, and therefore the line of divergence, or no variation, falls nearer to the true line on that side.

This is the actual state of the variation in the southern hemisphere; and from it we deduce the following important conclusion, viz: that there is an extensive tract of land or continent in high southern latitudes, and that its present magnetic centre is on or near the meridian of 10° W., and that it is not coincident with the terrestrial pole.

A British whaler is said to have lately coasted along a continent in the south seas, extending from lon. E. 47° 30′, to lon. W. 69° 29′; and this confirms an opinion we have always entertained on other grounds, that there is a continent in high southern latitudes. The direction of the South American line of no variation, which must pass not far from the centre of the continent, (being a simple true line, like that of North America) shows the relative extremes of longitude given by the captain to be correct, and consequently the situation of the continent; and yet it may extend considerably farther east and west, without altering the longitudinal position of the pole. At all events, the state of the variation in this hemisphere shows to an absolute demonstration, that there is but one cold or magnetic pole, which cannot be situated far from where we have placed it, as indicated by the true line of no variation.

This is further confirmed by the nature of the line of no variation passing east of Luzon and Borneo. A needle in that part of this line, north of the magnetic equator, and following the local equatorial flow to the Asiatic pole, (setting aside for the present that it is a virtual line) would note a westerly variation; but being affected in a measure by the westerly flow from the Philippine Islands toward the east, it points in a certain line due north; and it will be observed that it *almost* touches the east of Luzon. The continuation of this line, south of the magnetic equator, not only *touches*, but even *cuts*, the east coast of Borneo: which could not be the case, as the westerly flow toward the east from that large island must be far greater than that from Luzon, (and the rather because it is on the equator, and nearer the magnetic equator) and would consequently carry the needle east of due south at the island, and cause the line of no variation to pass far to the east of it, unless the equatorial flow were directed to a south pole much farther west from the meridian of the east of Borneo, than the Asiatic pole is from the meridian of the east of Luzon.

The same line also proves that there is no magnetic pole south of New Holland, though there is a line of no variation passing south through that vast island; for then the needle on the east of Borneo would point toward that pole, and note an easterly variation, and the westerly flow from that island toward the east would only increase the variation: in which case there could not be a line of no variation to the east of Borneo.

There is, according to M. Hansteen, a loop, of an elongated, pear-like form, in the Pacific ocean, between the parallels of 4° N. and 42° S. lat., crossing the meridian of 120° W., and denoting an easterly variation of 2°. As the variation increases without, it must decrease within it, and therefore there must be a line of no variation in it. This variation loop, and the others round it, are marked so as to show that it rests on doubtful authority; and it must be confessed, the variation in these parts is not well known, as it is but lately those seas have been frequented. After mature consideration, we cannot credit the variation thus laid down, because we cannot conceive easterly variation diminishing with increase of longitude, unless it approaches the confines of westerly variation; and still less can we conceive how easterly variation could diminish to 0, and then increase again.

It is possible, that in Africa, about lat. 17° N., lon. 10° E., there may be a centre of greatest heat, the hottest spot on the face of the earth, occasioned by vast deserts of sand, and separated from the magnetic equator by the lofty range of Central Africa. The variation would increase toward this spot from the lines of 15° and 20° west variation, laid down on the Chart. These lines of variation would be found to encircle the centre of greatest heat. At the centre, in all probability, the needle would be useless, on account of the calorific rays diverging. This is entirely hypothetical: but we certainly think it may take place, entailing with it another consequence, viz: two short *local* lines of no variation, one to the north and another to the south of this point.

By parity of reasoning, there will be lines of variation and no variation in the zones of neo-magnetic intensity; but they would most probably be more complex, and certainly more changeable, than those of the Asiatic continent; and, it should appear, vanish at the warm pole of those regions.

Somewhere near the line of magnetic confluence, the variation amounts to 90°, in consequence of the equatorial flow having reached its highest northerly course; and being deflected along the line of greatest cold, to the magnetic pole or point of greatest cold, carries the needle in a certain line due east and west. One point in this line is about latitude 75° N., lon. 62° W. This point is north of the parallel of the pole, and, on proceeding west through Barrow's Straits, the needle is directed to all the intermediate points of the compass, with its north end looking southerly, because the magnetic pole is then situated south of it. Near Cape Riley, lat. 74° 40′, lon. 92° W., it points south-west: about lon. 102° W., near Byam Martin's Island, it points due south; and about the south-east end of Melville Island, south-east. Now it is evident that the diverging calorific flow from the warm pole, will converge to the cold pole in these directions. (*Vide Chart.*)

We have hitherto been considering the phenomena of the variation and dip of the horizontal and vertical needles, supposing them in motion toward the higher latitudes; we shall now proceed to investigate the various phenomena attending them when stationary. And first, of the variation of the variation.

The variation at any given place is not constant, but continually changes; varying more in some places than in others, and irregularly at the same place; sometimes stationary for years, at other times varying greatly in the course of a year. This will be rendered evident by following the European virtual line of no variation. In the year 1580, the variation at London was 11° 15′ E.; in 1657, it was 0, and in 1832 it was 24° 30′ W.: so that the easterly variation decreased at the rate of 8′ 8″ per annum, and the westerly variation increased at the rate of 8′ 4″. From this it is plain, either that the American pole has increased in power, or approached nearer; or else that the Asiatic pole has grown weaker, or removed farther off. To determine which is the case is an easy matter, as we have fortunately sufficient data to go upon.

In the year 1657, the variation at Boston (subject only to the American pole, for the influence of that of Asia can hardly be appreciated there,) was about 11° W., and at the present time it is about 7° west, showing an alteration of only 4° in the variation in the course of 175 years, which clearly shows that the American pole has been *nearly stationary*. At the same time it must be borne in mind, that the severity of the winters in the United States has been gradually moderating, so that the pole *has not gained in intensity,* which is also proved by the ice in the Greenland seas having broken up, causing a reduction of arctic continental surface, the extent of which determines the degree of cold or intensity at its centre or magnetic pole. In the same number of years the westerly variation at London has increased 24° 30′; that is, London has been coming within the influence of the American or western pole, more and more every year. But the American pole exercises no more influence over London now, than formerly; for although we have shown, by the diminished variation at Boston, that it *may* be a little nearer to the meridian of that city, yet we have also shown that its intensity has been decreasing at the same time; so that its influence is essentially the same.

Now the virtual line of no variation, produced by the balance of power of the two poles, has moved eastward to the meridian of 45° E. of Greenwich; and as the American pole is of the same intensity as heretofore, the Asiatic pole has either moved east, or is of diminished intensity. The former supposition is not the case; because, when the Greenland seas and the north of Europe were blocked up with ice, the east of the northern coast must have suffered in like manner, as there was no outlet, (Bhering's Straits are nothing), and consequently the relative centre or magnetic pole *remained stationary as far as regards a longitudinal movement*, but gained in intensity proportionally with the increase of continental surface. If ever the accession of ice on the northern coasts of Asia caused the area of its arctic surface to equal that of America, its centre then became as cold as that of America, and the lines of the balance of their powers fell on meridians intermediate between the two, changing all the variation lines. As the outlet of the Greenland seas has re-opened, the ice has been diminishing, and with it the intensity of the Asiatic pole, causing the balance of power to approach gradually nearer that pole; so that this is the cause of the variation of the variation. Every accidental accession or diminution of the continental ice on the north of Asia, causes the virtual line of no variation to shift its position, to expand or contract its curve, and consequently causes a corresponding diminution or increase of the virtual variation throughout Europe.

The horizontal needle has also a diurnal variation of an indeterminate number of minutes east and west, which differs in different places, and in different seasons in the same place, both in time and extent; which furnishes a beautiful confirmation of the calorific theory of polarity.

It consists of four distinct oscillations or movements, two directed east, and two west. Taking the position of the needle at or about midnight, (which may be considered the real magnetic meridian or paropsis for the day), as its true position, it varies east of that line toward morning, travels westward again as sun-rise advances toward the meridian of the place of observation, and easterly again toward evening, when it returns west for the night to its true position. From this it appears that when it begins to shift, it first meets the sun, then follows it, then leaves it, and then precedes it in its diurnal path. Now, taking this theory as correct, it is a necessary consequence, and amounts to absolute demonstration.

It is well known that the coldest period of the day, (cæteris paribus), is just before sun-rise. If, then, the line of direction at or about midnight, be considered as the mean line of direction for the day, a spot somewhat to the east of it, (being nearly of the same temperature), will at its sun-rise be colder, and the equatorial flow at the spot of observation being deflected there, the needle will consequently turn easterly, and meet the sun; as sun-rise travels west, carrying the meridian of greatest cold with it, the equatorial flow is deflected west, till the hottest period of the day arrives, causing the needle to traverse in the sun's path; when arrived at a certain westerly deviation, as the more eastern meridians have cooled down, the equatorial flow returns toward the east; and when the temperature of the western meridians begins to cool, and consequently the flow from them to diminish in energy, the equatorial flow from the meridian of observation is deflected less from its natural direction, and, retrograding westerly, the needle obeys it, moving in advance of the sun, and settles to its mean direction for the night.

The diurnal variation is, in fact, a meridianal magnetic phenomenon; for any geographic meridian is cooler at sun-rise than another to the west of it, which causes a flow to the east, diverting the general equatorial flow and consequently the needle in that direction; as sun-rise commences over the westerly meridians, the flow from the now heated easterly ones carries the needle west, and as the eastern meridians cool down again, the flow from the west carries the needle east, and when the mean meridian has cooled down, it returns west and settles to it for the night.

The comparative extent of these four movements for any one day may perhaps be considered thus: The extreme of the *orient* variation, or that to meet sun-rise, is the greatest easterly variation for the day. The extreme of the *meridianal* variation, or that following the sun's path, and passing west over the magnetic meridian or paropsis of the day, is the greatest westerly variation. The extreme of the *retrograde* variation, or that in opposition to the sun, toward the east, is, perhaps, as many minutes east of the extreme westerly variation as the extreme of the orient variation is from the magnetic meridian of the day, and consequently not so far to the east as this latter; for the difference of temperature after sun-rise between the geographic meridian of the spot of observation, and that toward which the greatest retrograde variation is directed, is not so great as the difference of temperature before sun-rise between the geographic meridian of observation and that toward which the greatest orient variation is directed. The *occidental* variation, or that about sun-set, from the meridian of greatest retrograde variation to the magnetic meridian or paropsis, for the night, is necessarily less than the other movements.

We have been here considering the globe as even and uniform in surface, and the path of the sun as coincident with the ecliptic; thus obtaining a theoretical solution of the problem suitable to all times and places. We shall now state some of the existing diverting causes, and show why the actual diurnal variation does not agree at all times and places with our theoretical deductions.

It is to be observed, as before remarked, that the extent of these movements and the time of their occurrence are very irregular, not only as observed between distant places, but also in the same place, in the same season.

In the first place, the path of the sun in the ecliptic will materially affect the period of occurrence, and the duration as well as the extent of each of the daily movements, especially in the middle latitudes. For, as the time of sun-rise and sun-set is earlier or later, so will be the commencement of the first easterly and first westerly variation; and as in winter the time between sun-rise and mid-day and also between mid-day and sun-set is shorter than in summer, so will likewise the duration of these two movements be shorter in the former than in the latter season. But the duration of the second easterly and second westerly movement of any day, will (cæteris paribus) be greater in winter than in summer. In the middle latitudes, at the equinoxes, these movements would, perhaps, be of six hours each.

The extent of any regular diuernal movement will be greater (cæteris paribus) in the middle latitudes than in the tropics, because the difference of diurnal temperature is greater in the middle latitudes than in the tropics: and even when the difference is equal, the diurnal movement of the flow in the middle latitudes (or of the needle it governs) will cause a greater apparent variation from terrestrial polarity there, on account of its greater proximity to the terrestrial pole, when movements of the same magnitude subtend a greater angle.

Within the polar circles, these phenomena will be apparently more contradictory, but will admit of as easy a solution. In summer, at the northern sections, where the sun is continually above the horizon, there will most probably be found but two diurnal movements, the needle following the sun in its diurnal path. For as, when the sun is in the east of the meridian of observation, the atmosphere of the western meridians is (in these regions) the coolest, as being farthest from the direct influence of the solar rays, the general current from the spot of observation toward the cold pole is deflected westerly by the flow from the warmer eastern meridians; thus causing the diurnal variation of the general flow to follow the sun's path: and, when this luminary advances over the meridians west of the spot of observation, the eastern meridians cooling down with the declension of the sun after their mid-day, the general flow from the spot of observation is deflected easterly by the flow from the warmer western meridians; and, the sun returning east above the horizon, the needle follows it: its theoretical movement being 12 hours east and 12 hours west.

When, however, with the advance of the season, the sun disappears below the horizon, a modification takes place in the relation which one meridian bears to another with respect to heat; the conditions in this case being the same as in the middle latitudes; and when the sun disappears wholly below the horizon, the anomalous and uncertain diurnal variation which must then take place will depend, in the southern sections at least, on the alternate prevalence of the diurnal transmission of calorific currents from the eastern and western meridians of the middle latitudes, (reckoning from that of observation); and in the dead of winter, when the state of things is more settled, there will perhaps be little or no diurnal variation; or if there is, it must be attributed to the needle's proximity to the magnetic and terrestrial pole, where a very small actual movement will necessarily denote a very great variation.

It is also evident, that the different *relative* temperatures between the atmospheres of the land and of the fresh or salt waters, at different periods of the day and year, will cause periodically local diversions of the general flow, which will materially affect its variation, and the periods at which its easterly and westerly movements will take place, as well as their extent.

Thus, in New Wales and Labrador, east and west of Hudson's Bay, about the parallel of 55°, spring and autumn will develope some apparently anomalous phenomena.

In winter, when the bay is frozen over, the diurnal variation of these countries will follow the general rules laid down; it being, in effect, a continental surface. But when the ice breaks up in the spring, its superincumbent atmosphere is of a higher temperature than that of the regions east or west of it. When, therefore, sun-rise happens over the bay, its period of greatest daily cold, Labrador being situated east of it, has perhaps risen to an equal temperature; wherefore, the continuance, and, consequently, the extent, of the *meridianal*, or first westerly variation at Labrador, is checked early in the morning. But, New Wales being west of the bay, and perhaps being of the same temperature, when that of the latter is reduced at sun-rise, its *orient* variation will be checked simultaneously with the check of the meridianal variation at Labrador.

Also, as Labrador is bounded by salt water on the east, its *orient* variation would be checked early in the morning, because its atmospheric temperature may perhaps equal that of the eastern waters, when sun-rise happens to them; and, as the diurnal range of temperature is greater over the land than over the salt waters of these regions, the greatest difference of temperature between the meridians of Labrador and those of the eastern ocean happens in the afternoon; wherefore, the greatest easterly variation of the general flow at the eastern sections of Labrador, will take place at that period. And as New Wales is bounded on the east by a region of extensive fresh-water lakes, whose atmospheric temperature is below that of the surrounding lands; and as the difference of temperature between New Wales and this region of lakes is greatest when sun-rise happens to this latter, the morning will be the period of greatest westerly variation of the general flow at New Wales; that is, of the needle governed by it.

In the height of summer, as the atmospheric temperature of the land has risen more rapidly than that of the waters, the mean of each may be equal; and, consequently, the diurnal variation of these places will be subject to the general rules. But it is evident, that the approach of autumn will cause the same conditions as spring, and consequently the same anomalous variation.

An extensive region of clouds, also, preventing the usual nightly radiation of the eastern or western meridians, or the due diurnal increase of caloric to that of observation; or extensive storms of rain or snow, over the eastern meridians, when much caloric is given out, will cause the meridian of observation to be colder, perhaps, than the meridians to which its general flow should turn at any particular period; causing it, and consequently the needle, to be stationary, or even to make an apparently anomalous retrograde movement.

An extensive range of mountains, running north and south, will also change the period of occurrence of the greatest easterly and westerly diurnal variation; causing it to take place at the theoretical period of smallest variation.

Thus, the western coast of North America, being bounded east by the lofty range of the Rocky Mountains, its general equatorial flow will not be materially diverted by the effect of sun-rise on the meridians east of the range; for it will form a mechanical obstruction to the production of diverting westerly currents. Now, toward evening, the meridians of the western coast having cooled down, the calorific flow from the Pacific (having the sun above its western horizon) will cause the diversion of their general flow, easterly toward the mountains, to be greater then, than that which took place in the morning.

Also, as we have shown that the meridians immediately west of the mountains are protected by them, from the reduction of temperature which would have been occasioned by an easterly spread of caloric, when sun-rise happened to the east of them, it follows, that when sun-rise happens to the more westerly meridians, the former have a greater redundance of caloric to transmit westward than they would have, were this extensive range annihilated; so that the diverting flow is strongest from them toward the west: thus necessarily causing the greatest westerly movement in these regions to take place in the morning.

Accordingly, M. Hansteen observes, that the greatest easterly movement, on the north-western coast of America, takes place in the afternoon; and the greatest westerly movement in the forenoon.

As also Greenland and Iceland, in and near the circle, depend in a great measure, for their supply of caloric, from the southern regions, the period of greatest easterly and westerly movements will necessarily happen later in those countries; for the time requisite for the transmission must be taken into account, Accordingly, M. Hansteen notes a difference of three or four hours in the period of their occurrence at those places, as compared with (the middle sections, we presume, of) Europe and North America.

The diurnal variation is greater, at any given place, in summer, than in winter; because the meridianal difference of temperature is greater in summer; whereby the deflection of the equatorial flow toward the cool meridians is, greatest at that season. The reason of this will be better understood, when we come to treat of the intensity of the magnetic force.

It is nevertheless probable, that in the Bay of Bengal, the Sea of Arabia, and the Gulf of Mexico, being land-locked on the east, west and north, the diurnal variation is far greater than in the open ocean in the same latitudes. For the marine atmosphere of these regions is of a lower temperature than the terrestrial, and the eastern shores being heated before the western, this causes a flow to the west, diverting the needle in that direction; and as the western shore is heated afterwards, and the eastern cools down, the flow is then to the east, and diverts the needle in that direction. Now as the easterly and westerly flows are necessarily less in the open sea out of the influence of land, because of the reduction of temperature caused by the more rapid evaporation which takes place over a surface of water than over one of land, the meridianal difference of temperature is also reduced in the open sea, and it follows that the equatorial flow, and consequently the needle, is affected less, and marks a smaller diurnal variation there, than in these inland seas.

The diurnal variation will also be greater in those seas than on the land to the north of them, because the temperature is more equable over a surface of land, than over a mixed surface of land and water. In these seas also, the needle will mark a greater westerly variation on the eastern shores than on the western, and *vice versa*. The diurnal variation in the Sea of Arabia will be less than that in the Bay of Bengal, owing to the superior constancy of the westerly flow from the scorching sands of Africa.

The diurnal variation will perhaps amount to nothing when the needle shows an easterly or westerly variation of 90°, or a few degrees more or less: because being then on or near the parallel of the pole, the easterly or westerly diurnal movement of the pole will not affect the line of direction of the needle. But the amount of the monthly or solstitial variation (of which we are about to treat) occasioned by the pole shifting north and south, with the path of the sun in the ecliptic, will be more sensible there, than at the equator.

When the needle has reached the extreme of the easterly or westerly declinations, in its diurnal variation at any place, it remains stationary awhile; this is occasioned by the then equality of power of the two flows, before a re-action takes place in a contrary direction.

The diurnal variation will obviously be the same in those months in which the mean daily temperature is the same: because then the difference of meridianal temperature is the same, and consequently the equatorial flow is similarly affected by that diverting cause.

The monthly, or as it might with more propriety be called the *solstitial* variation, carrying the mean meridian of the diurnal variation easterly from the winter to the summer solstice, and westerly from the summer to the winter solstice, is owing to the particular disposition of the land within the circles.

As the poles shift with the path of the sun in the ecliptic, they do not move due north and south: for this supposes each continent of so regular a form, that the geographical meridian of the magnetic pole divides it into two equal portions, which is not the case. On inspection of the map, we perceive that there is more land on the north-east of arctic America, than on the north-west; so that whatever situation the pole holds, when the sun is on the tropic of Capricorn, it must shift north-easterly in order to retain its central continental situation, as the sun advances in its northern course; and the general equatorial flow being diverted toward that point, shifts the mean meridian of the diurnal variation easterly from day to day, from the winter to the summer solstice, when it has reached its maximum. As the sun retreats again from the northern tropic, the pole retrogrades south-westerly and carries the mean meridian of the diurnal variation westerly for the remaining six months.

This is the theoretical time of occurrence of the greatest easterly and westerly solstitial variations: but as the periods of greatest heat and cold actually happen a month or six weeks after the solstices, so will also the greatest solstitial variation.

We suspect that future observation will show that the solstitial variation is not so great in Asia as in America. Cape Taymour, on whose meridian the Asiatic pole is probably at present situated, is the most northern and projecting point of land, and will consequently cause the cold pole to move nearly on its meridian toward the geographic pole, when the mean meridian of solstitial variation, toward the southerly points of the compass, will necessarily measure a smaller angle than in the same relative situations with respect to the American pole. Yet, due east and west of it, the angle might perhaps be greater than due east and west of the American pole.

In consequence of the American pole shifting north-easterly and south-westerly, we suspect accurate observation will find that the solstitial variation is greater at any place east of the line of no variation, than in the same latitude and longitude west of the line, and that consequently the diurnal variation is proportionally affected. We have before stated that the shifting of the pole would shift the position of the line of no variation.

As we now come to treat on the subject of the dip as a distinct phenomenon, we propose first to consider the position which a needle might be supposed to assume at the sun, as the fountain of the caloric of our system, as also its position in voyaging to our earth, and the consequences of entering into an atmosphere. For it must be borne in mind, that the dipping needle, only, shows the true direction of the calorific current.

If we consider caloric, *in transitu*, as the cause of magnetism, and that the sun is the fountain from whence the caloric of our system emanates, then is magnetic intensity, or the directive force of caloric, greatest at the sun. As the radiation of caloric from its surface into space takes place in perpendicular lines, in all directions, a needle (supposing it to retain its form and properties there) would point perpendicular with its leading end or pole turned *from*, and its opposite end turned *to*, the centre of the sun. In advancing from that luminary, in any direction, the needle would point the same way, but the directive energy would be diminished. For the same volume of caloric is diffused through a wider space, as it spreads from a centre, and as the surface of the needle exposes the same area, the absolute volume impinging on it is diminished: the velocity, also, of that volume is continually diminishing, with every increase of distance, because the flow is occasioned by the difference of absolute volume at the source, and at the place of its ultimate destination, and as the difference approaches nearer to an equality at any intermediate spot, therefore the velocity is less: but the product of volume and velocity makes the effective force; therefore the power or intensity of magnetism decreases in *space*, with every increase of distance from its source.

We have hitherto been considering the needle as progressing from the sun in that conical section of space which supplies caloric to our earth or any other planet, without drawing any distinction between the horizontal or the dipping needles, for each would point the same way in their course through space, viz: in a heliocentric direction. On entering the atmosphere, however, it will be seen that this direction is changed.

As the earth is spherical, any given equatorial surface receives a larger supply of caloric from the sun direct, than an equal polar surface; so that there is a redundancy at the equator and a deficiency at the poles, causing a flow from the former to the latter. If then we imagine the plane of the equator produced to the confines of the atmosphere, it is evident the direction of the intercepted caloric on either side of this plane is now determined by the terrestrial difference of temperature just named. If, therefore, the needle entered the atmosphere north of this plane, its leading end would be deflected toward the north pole, and if south, toward the south pole, when its direction is no longer heliocentric. But the equatorial and polar difference of temperature, or the terrestrial horizontal force, is not the only power which now governs the direction of the flow; for on entering the atmosphere it becomes also subservient to the demand of evaporation, which causes a tendency from the atmosphere to the surface of the globe, or a vertical force. As every portion of caloric is subject to each influence, its course is between the horizontal and the vertical, or in what is called a dipping direction, which increases from the equator to the poles, where its direction is perpendicular or geocentric.

From hence it is plain, that the power of terrestrial magnetism, or the confluence of the horizontal and vertical forces affecting the direction and distribution of terrestrial caloric, is greatest at the equator on the surface, and diminishes with the increase of latitude and of altitude above the surface. For as, in entering the atmosphere, caloric has a tendency to converge to the centre of the earth, (being subject, like all other matter, to the force of gravitation) but on arriving at the surface, finds its free transmission in the same direction arrested, a superficial accumulation is the consequence. This causes the thermometric difference of the lower equatorial and polar atmospheres to exceed that of the upper equatorial and lower polar atmospheres: therefore the volume and velocity of the calorific flow from the lower equatorial atmosphere to the cold pole, exceeds that from the upper equatorial atmosphere; and as the product of volume and velocity makes the effective force of the calorific current, the energy of the magnetic power decreases from the surface of the earth, to the confines of the atmosphere in proportion to the altitude.

It also decreases with the increase of latitude from the equator. For as the volume of atmospheric caloric diminishes in proceeding from the equator, and as the density of the medium through which it moves to the poles increases with the latitude, causing its velocity to be retarded; and as the product of volume and velocity constitutes the effective force of the calorific current, its magnetic or directive power decreases in intensity from the equator to the poles.

Wherefore, also, both the horizontal and vertical forces decrease with the increase of latitude and altitude.

We have here been considering the ecliptic as coincident with the equator, and the earth even and uniform in figure and substance; but as this is not the case, the effect cannot be regular from the equator to the poles; the rule is therefore general, not particular. We have also stated, that on entering the atmosphere from space, the same end of the needle would point north or south according to which hemisphere it entered. Now as both ends of the needle are actually affected, one in each hemisphere, this appears to contradict the assertion; but when we come to explain the nature of the magnet, we shall show that each proposition is perfectly consistent.

As the amount of atmospheric caloric, at any given place, varies at different seasons of the year, and as the differences of temperature which produce the vertical and horizontal forces are continually varying at any given spot, not only relatively to each other, but also absolutely in their combined result, it follows that the magnetic power is continually varying, being greatest in summer and least in winter: yet this power cannot be measured by the dip.

To illustrate this, we will suppose that the vertical force acting upon the polar end of the needle, at one period of the year, is 10 grains, and that this is sufficient to bring the needle perpendicular; then if a force of 10 grains act on the same polar end in a horizontal direction, it will raise the needle, and, as the forces are equal, it will measure an angle of 45°; but the dip would be the same, were the powers doubled or trebled. Thus, the dip is no measure of absolute magnetic intensity, but only of the comparative intensity of the two powers, considered separately.

We have demonstrated (*Theo. VII.*) that the dip of the calorific current increases from the equator to the poles with the diminution of temperature; that is, that the general terrestrial diminution of temperature causes an increase of the dip, considering the needle in motion from a low to a high latitude. But yet on comparing the hot and cold periods of the year, the dip at any given place, especially in middle and higher latitudes, is greater in summer than in winter; that is, that when the needle is stationary, the annual local diminution of temperature causes a diminution of the local dip, and *vice versa;* for the dip is less in winter than in summer.

This is seemingly contradictory to the theory, but in reality it cannot be otherwise.

We have already shown why the dip increases with the latitude as the general terrestrial temperature *decreases:* we shall now show why the local dip increases as the solstitial temperature of the spot of observation *increases.*

In summer, the absolute volume of atmospheric caloric is greater than in winter, causing a proportionate increase of magnetic power: we have, therefore, only to trace the comparative intensity of the two forces, from known data, in order to arrive at the fact, whether the line of direction of the calorific flow, occasioned by their composition, has the same inclination in summer as in winter. If the forces are relatively the same, it will; if not, it will vary and alter the direction of the needle accordingly: being nearer the horizontal, if the horizontal force gains upon the vertical in comparative intensity; and nearer the perpendicular, if the vertical force gains upon the horizontal.

With every arithmetical increase of temperature, the capacity of the atmosphere to sustain vapor increases geometrically: that is, whatever the absolute volumes of atmospheric caloric in summer and winter, a larger *actual* as well as *comparative* volume is expended on evaporation in summer; its velocity is also augmented, for the lower strata of the atmosphere would become of a lower temperature than the upper, unless the velocity of the delivery kept pace with the increasing rapidity of terrestrial absorption; and the product of volume and velocity constituting the effective power, as both increase, *the vertical force actually and comparatively increases from winter to summer.* Also, every mean diurnal increase of temperature, at the spot of observation, causes a decrease of the difference of temperature between that spot and the pole, because the annual extremes of temperature there are less than at the pole. This difference governs the velocity of the flow from thence to the pole; and as the temperature decreases in an arithmetical ratio, the velocity of the flow also decreases in the same ratio; the actual volume also transmitted in summer from any given spot of observation, is less than in winter, being the residue of an arithmetically increasing volume from which a geometrical increase is deducted, term for term, to answer the demand of evaporation; and as the product of volume and velocity makes the effective force, and both decrease, *the horizontal intensity actually and comparatively decreases from winter to summer.* Hence, as the vertical force gains, and the horizontal loses, the ratio of the hybernal forces is destroyed in favor of the former, the calorific flow approaches nearer to the perpendicular, and the needle measures a greater dip in the summer. These acting causes are at their maximum about the aphelion, when the dip is at the greatest, and being reversed with the approach of winter, the effect also is reversed, and the needle measures a smaller dip, till its inclination is smallest about the perihelion. This may be exemplified numerically.

Let us take London and New York, each obeying the same pole, as the spots of observation. The solstitial temperature ranges between 24° and 87° at the former place, and 15° and 90° at the latter: at the pole, the range is between — 60° and + 42°, for it is rarely higher, in consequence of the immense bodies of ice in those regions. By this it appears that the solstitial range of temperature at London and at New York amounts to 63° and 75° respectively; and at the pole to 102°; showing that the greatest solstitial range takes place at the pole; and, as New York is nearer to the pole than London, that as a general rule the solstitial range decreases as the polar distance increases, and is least in the magnetic torrid zone. The mean greatest and least difference of solstitial temperature between London and the pole, is 84° in winter and 45° in summer; the corresponding differences between New York and the pole, are 75° and 48°, showing that the temperatures of these (and any) places and the pole, are more nearly equalized in summer than in winter, causing a proportionate decrease of horizontal intensity, and consequent increase of the dip at the former season.

Hence it is evident, that the annual variation of the dip ranges from day to day between the extremes of the solstitial variation. Hence also, the variation of the dip at corresponding periods between the two solstices, that is, when the mean monthly and daily temperatures are equal, should coincide; but as this supposes the variations of temperature uniform and equable from day to day, which is not the case, the mean only of the monthly variations will probably be found to agree. The mean of the solstitial variation is the true dip of any place, and would most likely equal the equinoctial dip.

But this is not the only phenomenon which is, at first sight, contradictory to the theory. All relative changes of temperature between the pole and the spot of observation affect the dip, and therefore it is varied every hour of the day; being greater in the forenoon than in the afternoon.

Now, on a comparison of the solstitial changes of temperature affecting the local variation of the dip, we find it is least at the *coldest* period of the year; and yet the diurnal changes of temperature affecting its local variation causes the smallest dip to happen at the *hottest* period of the day. It must be borne in mind, however, that the *solstitial increase* of temperature causes the difference of temperature between the spot of observation and the pole to *decrease from day to day*, by reason of the greater solstitial variation of temperature at the pole than at any place between it and the equator; thereby causing a *decreasing* horizontal demand from day to day, from the winter to the summer solstice. The *diurnal increase* of temperature, on the contrary, produces an opposite result; that is, it causes the difference of local and polar temperature to *increase from hour to hour*, in consequence of the smaller diurnal variation of temperature at the pole than at the spot of observation; thereby causing an *increasing* horizontal demand from hour to hour, as the day advances to the hottest period. A numerical illustration of the increase and decrease of the diurnal dip may not be unadvisable.

Let us again take London and New York as the spots of observation. The diurnal range of temperature at the summer solstice may be taken at 66° about sun-rise, and 87° about 3 P. M. for the one; and 75° and 90° for the other, at the corresponding periods: that of the pole being considered as stationary at 42°. Therefore, the greatest diurnal difference of temperature between these places and the pole, at the summer solstice, is 45° and 48° respectively, and this occurs about 3 P. M.; showing that the greatest horizontal intensity for the day at these (or any) places, occurs at the hottest period. The diurnal difference of local temperature at the solstice is 21° and 15° respectively. The same effect will be found to take place at the winter solstice: but the diurnal range of temperature, at any place, being less at that season, and the temperature of the pole, though low, being still considered stationary, the diurnal variation of the horizontal intensity is confined to a smaller range.

With a knowledge of these particulars, we are thoroughly prepared to comprehend the reason of the dip being least in the afternoon, and greatest in the forenoon. As the day advances, the local temperature rises, and with it magnetic intensity increases; therefore one or both of the forces must increase. Now, evaporation is carried on at a more rapid rate with every increase of temperature, so that the vertical force is *actually* greater in the afternoon than in the forenoon: but the dip decreases; therefore, the horizontal force must increase *comparatively* on the vertical force; and as this latter increases actually, therefore also the horizontal force increases both actually and comparatively on the vertical, from the forenoon to the afternoon. Unless this is the case, the phenomenon of the decrease of the dip with the increase of diurnal temperature, cannot take place. Therefore we must prove, that *with the diurnal increase of temperature, the horizontal force increases in intensity in a greater ratio than the vertical.*

Whatever the horizontal force at the perihelion, it decreases from that time to the aphelion, because the difference of the local and polar temperatures is reduced from the former to the latter period; causing a corresponding decrease in the volume and velocity of the horizontal transmission, as before proved. Therefore, when the morning temperature at New York, at or about the aphelion, is 66°, the difference of local and polar temperature, or the horizontal force, is at its minimum, wherefore the dip is at its maximum. Now, as the temperature increases from hour to hour, till it reaches 90° about 3 P. M., evaporation goes on more rapidly, causing a greater vertical force both actually and comparatively with the morning vertical force, and were this the only effect the dip would be increased. But the same increased temperature which causes an augmentation of the vertical force, causes also an augmentation of the difference of local and polar temperature, that is, an *actually* increased horizontal force. Now it is plain, that if the geometrical increase of the vertical force and the continual *decrease* of the horizontal force, from the winter to the summer solstice, causes an *increase* of the dip, whenever the above conditions are destroyed the effect must vary accordingly. But we have shown, that during the diurnal increase of temperature, the vertical force continues to increase geometrically, but that the horizontal force, instead of decreasing, *increases* continually; therefore, the horizontal force gains *comparatively* upon the vertical, with the increase of diurnal temperature. The relative intensity of the two forces is now *actually* and *comparatively* altered; and as this takes place in favor of the horizontal, the calorific flow approaches nearer to the horizon, and the needle measures the smallest dip at the hottest period of the day.

The diurnal increase of temperature is in fact only a temporary counteraction of the effects of the solstitial action.

These acting causes are at their maximum about 3 P. M., and being afterwards reversed, as the diurnal solar delivery diminishes, the effects also are reversed, and the needle measures the greatest dip, perhaps, a little before sun-rise. As these causes increase in effect from the winter to the summer solstice, and then decrease, the diurnal variation of the dip must increase and decrease in like ratio. Hence, the mean of the diurnal variation should be considered as the real local dip for the day: hence, also, the mean of the diurnal variation of the dip would be found to agree at the corresponding periods of solstitial increase and decrease of temperature; and the mean of the equinoctial diurnal variation would (theoretically) correspond with the mean of the solstitial variation, or mean local dip.

But, although it is very good in theory to consider the solstitial increase and decrease of temperature uniform from day to day, yet the fact is not so; and therefore the solstitial and diurnal variations of the dip are not regular in their increase or decrease: and as the hottest and coldest periods of the year are not coincident with the solstices, but occur some time after, for the same physical reasons that the hottest period of the day is after the sun has passed the meridian; therefore, the greatest and least local dip are not coincident with the solstices, but fall some time after. Hence, the mean of the local dip will not happen at the equinoxes, but at the meso-thermal division of the year, after the equinoxes. Yet as the theoretic time of maximum and minimum dip facilitates calculation materially, we shall assume it throughout, without considering ourselves in error. The correction for time can easily be made, when the theoretical deduction is arrived at.

M. Hansteen says, that the dip is 15′ greater at the aphelion than at the perihelion, and 5′ greater in the forenoon than in the afternoon. These conclusions were derived from the mean of various observations, chiefly made in different parts of Europe: in England, Norway, Sweden, Denmark, and Russia: and, therefore, cannot be the true mean for every place in this extensive tract, included between the dipping lines of 70° and 75°.

Now, the ratio of the solstitial range of temperature, in the south of England, (about 63°) is to the diurnal range of temperature there, at the summer solstice, (about 21°) as 15 to 5. As these ranges of temperature govern the solstitial and diurnal ranges of the dip at the summer solstice, 15′ may be assumed, for the sake of argument, as the extreme range of the dip at London, from the summer to the winter solstice, and *vice versa*; and 5′ as the diurnal range of the dip at the summer solstice.

From this, we can easily comprehend the apparently contradictory local variations of the solstitial and diurnal ranges of the dip. Every solstitial and diurnal difference of temperature will produce a different effect; and as no two places can have the same conditions at the same time, the results in the variation of the dip must be infinite.

Let us examine the conditions of St. Petersburgh and New York, at the summer solstice; both situated, like London, between the 70th and 75th parallels of equal dip. The solstitial range of temperature, at St. Petersburgh, is greater than at London, because its situation is continental inland, and in a higher northern latitude; therefore, the solstitial variation of the dip is more than 15′; but the diurnal range of temperature is less, because the sun is two hours longer above the horizon then, than at London; therefore, the diurnal variation of the dip is less than 5′. At New York, the solstitial variation of temperature is greater than at London, because it is on the eastern coast of the continent, (the reason hereafter) and nearer the magnetic pole; therefore, the solstitial variation of the dip will be more than 15′: but the diurnal range of temperature is less than at London, because it is nearer to the tropic; therefore, the diurnal variation of the dip will be less than 5′.

It follows, therefore, that the solstitial and diurnal ranges of the dip are as the solstitial and diurnal ranges of temperature.

Hence, at any place in the middle latitudes, on the 21st of June, the ratio of the diurnal variation of the dip to the whole solstitial variation, is as the diurnal range of temperature of that day to the whole solstitial range of temperature.

Hence, also, as the dip is at its minimum, at the winter solstice, and at its maximum at the summer solstice, the ratio of the diurnal variation of the dip, at any given day after the winter solstice, (or at its complemental period after the summer solstice) is to the amount of the whole solstitial variation accomplished at that day, as the diurnal range of temperature at that day is to the then existing difference of local and polar temperature.

The dip (that is, the inclination of the terrestrial currents of caloric) we have shown to arise simply from the difference of local and polar temperature, causing certain ratios of calorific expenditure in evaporation and polar transmission.

We shall now consider the peculiarities of fluctuation to which the dip must be subject in certain parts of the earth, in consequence of the sun's apparent path in the ecliptic.

If the sun's annual and diurnal path were coincident with the equator, the diurnal delivery of caloric to any place would be equable from day to day, producing an uniform equatorial flow to the cold poles, from day to day. This would cause the solstitial variation of the dip to cease. Yet the hourly delivery would alter the absolute volume of any place as the sun approached the meridian, so that the diurnal variation of the dip would still exist, being greatest in the middle latitudes, and vanishing at the equator and the poles.

Now, as the sun moves north and south in the ecliptic, the absolute volume of caloric delivered at any place varies from day to day, as its obliquity increases or decreases, causing a variation in the dip from day to day; which, as it increases in the middle latitudes for six months, as the sun approaches their tropic, and decreases again for six months as the sun recedes to the opposite tropic, we have called the solstitial variation of the dip. This apparent motion of the sun is confined to a limited number of degrees, about the parallels of 23° 28′, at present, on each side of the equator, which are thence called the two tropics: this causes his absence and presence, for one entire revolution, at the parallels of 23° 28′ from the geographical poles, called the polar circles. There is, consequently, a region between each tropic and its respective circle, over which the sun is never vertical, and is never absent or present for one entire diurnal revolution. This gives rise to the geographical division of the globe into three zones in each hemisphere; each of which is affected by peculiar annual and diurnal fluctuations of temperature.

With regard to the solstitial fluctuation, it is least in the torrid zone, and greatest in the frigid; therefore, in the temperate zone, it is at a medium: the northern sections approximating to the character of the frigid, and the southern to that of the torrid zone. With regard to the diurnal fluctuation of temperature, it is greatest in the temperate zone, and least at the frigid, the medium being in the torrid zone, at the equator. Concerning the periods of maximum and minimum diurnal fluctuation, they will not be equal in number, or simultaneous in their occurrence, in the three zones; but will vary in a remarkable manner.

We shall examine the conditions of each zone separately, and then trace the probable manner in which they will be found to affect the dip. We should premise, that we consider the period of greatest solar proximity, and consequent greatest delivery of caloric, as coincident with the period of maximum heat or maximum magnetic intensity; and the period of greatest solar distance as coincident with the period of minimum heat or minimum magnetic intensity. This only affects the time at which the magnetic phenomena exhibited by the needle, take place; causing a theoretical occurrence of the solstitial and diurnal phenomena some days and hours respectively in advance of the actual; and as the error in point of time is easily corrected, we prefer this mode of proceeding. We shall also set aside, at present, the effects of localities, considering the earth as of an even and uniform surface.

On the 22d of December, the sun is vertical to the southern tropic, and consequently oblique to all places in the torrid zone. As on its return northerly, the southerly obliquity diminishes to every place in succession from day to day, till it vanishes, when a northerly obliquity commences, the winter solstice may be considered a period of maximum diurnal range of temperature throughout the north torrid zone; the greatest range taking place at the northern sections, and the least at the southern. On the 21st of June, the sun is vertical over the northern tropic, causing another maximum range of diurnal temperature throughout the north torrid zone; the greatest range taking place at the southern sections, and the least at the northern. As the equator is between the two tropics, the range there is equal at both periods; and as the range of diurnal temperature from tropic to tropic is an arithmetical series, read in an increasing order for six months, and in a decreasing order for another six months, the sum of the two maximum ranges of temperature, at any place, are equal to twice the equatorial maximum range.

Thus, the maximum diurnal ranges of temperature, throughout the torrid zone, are simultaneous at the solstices, but unequal in amount at any two parallels on the same day, except at the equator. The two minimum diurnal ranges, on the contrary, are equal at all, but simultaneous at no two parallels: they are equal, because they consist in a vertical sun, when the diurnal amount of caloric delivered is equal, and the nightly radiation is equal; and they are not simultaneous, because the sun is not simultaneously but successively vertical, moving at the rate of about 15′ 28″ of latitude daily. We take no notice of his hourly path in the ecliptic.

When the sun is on the southern tropic, it is at its greatest obliquity to the temperate zone, (we refer only to the northern hemisphere.) This, then, is the period of maximum cold in that zone. As the southern sections partake of the character of the northern sections of the torrid zone, the diurnal range of temperature there is at its maximum on the 22d of December; and as in the northern sections the sun is but a short time above the horizon, and his rays tangential to the surface, they do not affect the temperature sensibly, so that the diurnal range of temperature is at its minimum there on the same day. As the sun advances north, the diurnal range diminishes in the southern sections, while it increases in the northern.

When the sun is on the northern tropic, it is at its least obliquity to the temperate zone, and consequently the diurnal range of temperature in the southern sections is at its minimum, because his rays are nearly vertical to them, and the days and nights are nearly equal. On the same day the diurnal range of the northern sections is also at its minimum a second time, because the sun is above the horizon the greater part of the twenty-four hours. At the equinoxes, when the sun has advanced or receded to the equator, the northern sections are at their maximum range of diurnal temperature, because their day and night are equal, while on the same days the southern sections are at their medium range. The middle sections will agree with the northern sections in the periods of maximum, medium, and minimum range of diurnal temperature.

Thus, in the southern sections of the temperate zone, there is but one maximum and one minimum range of diurnal temperature throughout the year, coincident with the summer and winter solstices; while in the middle and northern sections there are two maximum ranges, coincident with the equinoxes; and two minimum ranges, coincident with the solstices.

When the sun is on the southern tropic, it is below the horizon of the whole frigid zone for twenty-four hours; and therefore the diurnal range of temperature is then at its minimum in that zone, because there is no alternation of day and night. As the sun advances to the north, day dawns on the southernmost sections, and causes a diurnal alternation of temperature there: the rest is still in darkness; so that the change from minimum to maximum range takes place from the winter solstice, and proceeds northerly from day to day, till the equinox, when the sun rises to the pole, and the zone has equal day and equal night. The pole is then turned to the sun for six months, while the neighboring sections have days and nights of proportionally diminishing lengths with the increase of latitude from the pole. This causes a steadily increasing supply of caloric to the pole and northernmost sections, for three months; and an intermittent increasing diurnal supply to the southern sections for six months; also, a steadily decreasing supply to the pole and northernmost sections for three months; and an intermittent decreasing diurnal supply to the southernmost sections for six months.

Thus, the southern sections have their maximum diurnal range of temperature occurring about the equinoxes, and their minimum range at the solstices; while at the pole and northernmost sections there is no diurnal range.

We may remark here, incidentally, that it is evident, from the above, there is a northerly flow from the terrestrial pole toward the south, during the northern summer, more particularly during the night, at the southern sections of the frigid zone.

We shall now give a tabular view of the periods of maximum, medium, and minimum range of diurnal temperature, in each northern zone; dividing them into three equal sections, a southern, a middle, and a northern; each considered as a whole, and leave the inference to be applied to the southern hemisphere. To subdivide them further would be laborious and useless in an elementary treatise. We shall then proceed to our theoretical deductions respecting the occurrence of phenomena, which, we suspect, future accurate observations may detect in the dip, in different latitudes, and which at present appear anomalous and irregular.

TABULAR VIEW

OF DIURNAL RANGE OF TEMPERATURE.

	N. Torrid Zone.			N. Temp. Zone.			N. Frigid Zone.		
	s. sec	m.sec.	n. sec.	s. sec.	m.sec.	n. sec.	s. sec.	m.sec.	n. sec.
Dec. 22	Max.	Max.	Max.	Max.	Min.	Min.	Min.	Uncertain.	Steady.
Feb. 5, Nov. 6	Med.				Med.	Med.	Med.		
Mar. 6, Oct. 6		Med.							
Mar.21, Sep21			Med.	Med.	Max.	Max.	Max.		
Apr. 5, Sept. 6	Min.								
May 6, Aug. 6		Min.			Med.	Med.	Med.		
June 6, July 6			Min.						
June 21	Max.	Med.	Min.	Min.	Min.	Min.	Min.		

1. ***With respect to the exhibition of solstitial phenomena affecting the dip.***

As on the 22d of December, when the sun is on the southern tropic, the north torrid zone, as well as the magnetic pole, are at their lowest temperatures, and as the vertical force decreases in comparison with the horizontal, with the solstitial decrease of temperature, therefore the dip is then at its minimum in that zone.

On the 21st of June, when the sun is on the northern tropic, as the magnetic pole is at its highest temperature, while the northern sections of the torrid zone are at their highest, the middle at their medium, and the southern at their lowest temperatures, the solstitial dip will be at its maximum on that day in the northern sections, at its minimum in the southern, and consequently at its medium in the middle sections.

About the 5th of April, when the sun has advanced a little north of the equator, so as to be vertical over the middle of the southern sections, as they have then acquired their highest temperature, and as the middle and northern sections have also increased in temperature as well as the pole, and as the solstitial increase of temperature, at the spot of observation and at the pole, by reducing the comparative power of the horizontal force, causes an increase of the dip, therefore the dip will then be at its maximum in the southern sections; near its maximum in the middle, and at its medium in the northern sections. Superficial reasoning might suppose, from what we have before laid down, (viz: that the local increase of temperature, from solstice to solstice, causes an increase of the dip) that the dip would also be at its maximum, in the southern sections, about the 6th September, when the sun is again vertical to the middle of the southern sections; instead of which, a diminution of the dip will be the consequence. For the solstitial increase of local temperature causes a local increase of the dip when the pole also *rises* in temperature, thus causing a *reduction* of the local and polar differences of temperature, that is, of the horizontal force: but if the conditions which produce this phenomenon be reversed, the phenomenon must be reversed also. Now on the day mentioned, the temperature of the southern sections is *increased*, because the sun becomes vertical to them, while that of the pole is *decreased*, as winter approaches, thus causing an *increase* of the local and polar difference of temperature; that is, of the horizontal force; and as the rate of evaporation or the vertical force is the same at both periods of local maximum temperature, therefore the ratio of the forces is destroyed in favor of the horizontal, and a diminution of the dip must be the consequence.

Hence, within the northern tropics, whatever the dip at any place, when the sun is vertical to it, after the winter solstice, it measures a smaller angle on the return of that luminary to it after the summer solstice.

At the vernal equinox, the southern sections will manifestly be approaching their maximum, and the middle and northern sections their medium dip.

At the autumnal equinox, the dip of the parts bordering on the equator will be reduced, as before proved, the summer solstice being past. And that of the middle and northern sections will likewise be reduced, because their temperature being reduced after the solstice as well as that of the pole, they become subject to the general rule.

On the 22d of December, the difference of local and polar temperature throughout the temperate zone being at its maximum, the local dip is at its minimum; and on the 21st of June, being at its minimum, the local dip will be at its maximum, as before shown. As on the advance and retreat of the sun, the increase or decrease of local temperature is simultaneous with that of the pole, there are no anomalous deviations from the general rule of a steady increase and decrease of the local dip with the solstitial increase and decrease of local temperature.

It is difficult to give any opinion upon the solstitial phenomena that may be exhibited in the frigid zone. On the 22d of December, however, the sun is on the southern tropic and below the horizon of the southern sections of the frigid zone: at the same time, the cold or magnetic pole has moved south for the winter season, to lat. 70° 30′ N., coinciding with the middle of the southern sections, according to its position observed by Capt. Ross at that time of the year. The dip, therefore, of the parts more immediately south of and around the pole will be nearly vertical; decreasing with the increase of longitude east or west from the meridian of the pole.

When the sun has advanced upon the northern tropic, the cold pole has retreated north to the latitude of 72° 30′, according to its position observed by Capt. Parry at that season; thus causing a sensible increase of the winter distance (140 miles, or nearly one half,) between itself and the southernmost sections; while those parts far east and west of its meridian do not perceive a sensible increase of that distance. But as it is the same thing whether the needle move south from the pole, or the pole north from the needle, and as a decrease of the dip is the consequence in the first case, so would it be in the second; and hence, the increase and decrease of the solstitial dip in the southern sections of the frigid zone would be more sensibly perceived, perhaps, south of the pole, than far east or west of its meridian; unless indeed we conceive that the increase of evaporation at these last mentioned parts may destroy the ratio of the hybernal forces in its own favor, (which is not improbable) when the increase of the solstitial dip will be greater than at the parts south of the pole.

Inasmuch, however, as the cold pole of America moves east of north, it will increase its distance to those parts which are west, and decrease its distance to those which are east of its winter meridian; thus increasing the dip of those parts immediately east of it, and decreasing that of those parts immediately west of it, from the winter to the summer solstice: and producing a contrary effect as it retreated south-west.

With respect to the solstitial effects on the dip in the middle and northern sections, they would depend on so many causes, that it is almost impossible to draw any conclusion.

But the annual path of the sun in the ecliptic will also have another very anomalous effect on the solstitial dip in some of the southern portions of the north torrid zone. From lon. E. 25°, easterly to lon. 175° W., the magnetic equator passes north of the equinoctial, causing as a necessary consequence, the solstitial phenomena of those parts of the north torrid zone, which are south of it, to be reversed. For, as their general flow is to the south magnetic pole, when the sun is vertical to them after the northern summer, the conditions are an increase of local and polar temperature; wherefore the dip increases in these sections, while it decreases in the sections west of the longitude of 25° E., where the magnetic equator is south of the equinoctial.

Another curious effect will be the *libration* of the dip in those sections which comprehend the magnetic tropics. For, as they will be alternately subject to the influence of the northern and southern magnetic poles, so will the dip be to the north or south accordingly.

2. *With reference to the exhibition of diurnal phenomena affecting the dip.*

As the maximum diurnal range of temperature has been proved to cause a maximum, and the minimum diurnal range of temperature, a minimum diurnal range of the dip; we have only to look in the table for the maximum, medium, and minimum diurnal ranges of temperature in any given section of either zone, and against it we shall find the theoretical day of the month on which it happens; but it must be borne in mind, as before remarked, that the actual phenomenon always happens later than the theoretical.

It must not be imagined, however, that all the maximum or all the minimum ranges, for any given section of a zone, are equal as a necessary consequence. Thus, with respect to the southern sections of the north torrid zone, it must not be supposed that the ranges of the dip are equal at the two solstices, because the diurnal ranges of temperature are then at their maximum: for, as the sun is nearer to those sections at the summer than at the winter solstice, so is their maximum diurnal range less at the former than at the latter season, and consequently, the diurnal range of the dip. The term *maximum* only means the greatest, and the term *minimum* the least effect, before a counterchange takes place.

It remains now to treat on the nature of the intensity of the magnetic needle.

If a horizontal needle be allowed to settle to the magnetic meridian, and then be diverted at any angle, say 30°, it will, when released, return to the meridian; and, as it has acquired considerable velocity in so doing, it will pass many degrees on the other side of it, and in returning pass it again. It will continue to do thus till it settles, every arc it measures being less than the preceding. The same thing happens when the vertical needle is diverted from the meridian of the dip in the plane of its action. The velocity with which this phenomenon is attended is called *the intensity of the magnetic needle.*

It has been thought that the needle moves through equal arcs in equal times, reckoning from the beginning to the end of an oscillation, (for the equal divisions of an oscillation are performed in unequal times,) that is, it moves through one arc of 30°, two arcs of 15°, three arcs of 10°, or five arcs of 6°, in the same time, at the same period of the day and year; yet the time of performance varies at different periods of the day and year. This ratio of oscillation may, perhaps, want confirmation; it is certain, however, that it moves through the smaller arcs of oscillation with greater velocity than through the large, and, consequently, performs them in shorter times.

This is beautifully in accordance with the theory that a material flow is the cause of magnetism. For, if we place a needle of any metal with a leading end athwart a stream of water, it will turn with accelerating velocity, cross the line of direction, and, when its initial velocity is so far retarded by proceeding against the current as to equal its velocity, it will return. Every succeeding oscillation will be less than the preceding, and it will finally settle in the direction of the stream. If the velocity of the current be increased, it will move quickly in small arcs, and if it be diminished, slowly in large arcs. It must be borne in mind that the motions of the needle would also depend on the specific gravity of the fluid, as well as on its velocity.

Let us see how the laws which govern the motions of bodies in fluids accord with the phenomena exhibited by the horizontal needle in different latitudes and longitudes, and at the same spot at different periods of the year and day, under the supposition of the external action of a material calorific flow. We should premise that the vertical force is out of the question in treating of the horizontal needle, as the construction of the instrument supposes it to be annulled.

The horizontal needle, if diverted at any given angle from the magnetic meridian, when near the magnetic equator, makes a certain number of oscillations in a given time; that is, moves with a certain intensity; which number of oscillations or intensity decreases with every degree of magnetic latitude to the magnetic pole, where the needle will not traverse at all.

As the excess of temperature or absolute volume of caloric at the equator above that of the pole is greater than that of any intermediate place and the pole, it follows that the absolute volume and velocity of the flow, from the equator, is greatest, and, consequently, the force of the calorific current, or magnetic intensity, is greater there than elsewhere: that is to say, the needle, in returning to the meridian at the equator, will move quickly in small arcs, and thus make a greater number of oscillations in a given time than elsewhere. Of intermediate places, the intensity will be greatest at the least remote from the equator. This supposes there are no inequalities of surface or disposition; but as this is not the case, the rule is general, not particular.

In the regions near the magnetic pole, the needle will not traverse at all, or very faintly. This is not owing to the cessation of the magnetic directive power, for the dipping needle will still traverse briskly, but because the direction of the calorific currents, in those parts, is almost vertical to the blade, causing their geographical progression to be almost imperceptible; thus, a common horizontal vane will not obey a descending current of air.

The intensity in the middle latitudes is, perhaps, sometimes greater than within the tropics, and the reason is easily assigned.

When this is the case, the temperature of these places is, perhaps, as high as 90°, while, within the tropics over the ocean, the temperature is, perhaps, only 85°. In this case, as the tropical ocean bears a larger proportional surface to the tropical land, than the ocean in the middle latitudes does to the land there, a larger proportion of the tropical volume is diffused to the east and west, than is the case in the middle latitudes: also, as the difference of local and polar temperature is then greater in the middle, than in the lower latitudes, the absolute volume and its velocity of transmission to the pole, that is, the horizontal intensity, is greater in the middle than in the lower latitudes.

If, in the middle latitudes, a needle be diverted from the magnetic meridian, at any given angle, it will, in summer, make a certain number of oscillations in a given time, and, in winter, a certain greater number: this is a comparison of the intensity at the hot and cold periods of the year. If it be diverted at any given angle, it will make a certain number of oscillations in the morning, and a certain greater number in the afternoon, the greatest number occurring about the hottest period: this is a comparison of the hot and cold periods of the day.

These facts the world owes to the indefatigable labors of M. Hansteen, who has done more for the cause of magnetism than any other individual. At first sight, they appear totally at variance with the calorific theory; for it seems that the greatest annual intensity is at the *coldest* period of the year, while the greatest diurnal intensity occurs at the *hottest* period of the day. Yet, in reality, this must follow, if the theory of a calorific flow be allowed as the cause of magnetism.

In order to unravel this apparent contradiction, we must beg to remind our readers that the needle is governed by a flow of caloric; that this flow is occasioned by the difference of atmospheric temperature between the spot of observation and the governing pole; and that the absolute volume of the current and its velocity is in direct proportion to the amount of the difference. We have before shown, in treating on the variation of the dip, that the momentum of the horizontal force increases from summer to winter of any given year, and from A. M. to P. M. of any given day; therefore, the horizontal needle, if subject to the calorific flow, must make a greater number of oscillations in winter than in summer, and in the afternoon than in the forenoon.

Yet, as this summary mode of accounting for it may not be considered sufficient, we shall give a numerical illustration of it, taking the city of New York as the spot of observation.

Let us compare, first, the elements of the horizontal intensity, at the summer and winter solstices. The temperature at New York at the former season may be 90°, while at the pole it is only about 42°; the difference is 48°: the winter temperatures at the solstice may be taken as + 10° and — 60° respectively: the difference is 70°. So that the momentum of the summer flow at New York is to that of the winter flow as 48 to 70; showing that the intensity of the calorific flow is greatest in the winter, or coldest period of the year, and that, consequently, the needle should make a greater number of oscillations in winter than in summer.

Let us now compare the elements of the forenoon and afternoon of any given day, say the summer solstice. The temperature at New York, about sun-rise, may be 63°, and at the pole 42°; the difference is 21°: at three, P. M. the temperature at New York may be 90°, while at the pole the temperature is still 42°, (the diurnal range of temperature there being then very small, if any;) the difference is 48°. So that the morning flow at New York is to the afternoon flow, as 21 to 48; showing that the intensity of the calorific flow is greatest in the afternoon, or hottest period of any given day during summer: and that, consequently, the needle should make a greater number of oscillations in the afternoon than in the forenoon, if subject to the calorific flow.

The same effects will be found to obtain in winter; but, as the diurnal range of temperature is less then than in summer, they will not be so perceptible. The fact is, the solstitial increase of temperature, at any given place, as before remarked, causes a diminished difference of temperature between that place and the pole, in consequence of the greater solstitial range of temperature at the pole than at any other place; while, on the contrary, the diurnal increase of temperature, at any given place, increases the difference of temperature between that place and the pole; causing, in the former case, a diminished, and in the latter, an increased horizontal force.

As we have determined that the horizontal intensity at New York, at the summer solstice, when the temperature is 90°, is to the horizontal intensity at the winter solstice when the temperature is 10°, as 48 to 70; and that the horizontal intensity in the morning, at the summer solstice, is to the horizontal intensity in the afternoon, as 21 to 48; it may be asked, why then are not these figures the actual ratio of the oscillations at those periods? We reply, that the needle is not oscillating in a medium of caloric only, and that, consequently, other elements are to be taken into consideration. It is obvious, that whatever the number of oscillations performed at the equinoxes, in winter, when the horizontal intensity is greatest, the density of the atmosphere is augmented, and, consequently, the resistance which it opposes to the vibrations of the instrument is increased, causing the number of vibrations to be diminished; and, in summer, though the horizontal intensity is weakest, yet the atmosphere is at its greatest rarity, and thus, an obstruction to the freedom of oscillation being removed, the needle makes a greater proportional number of oscillations. The same reasoning will show that the very reverse must take place during the course of the day.

But even these are not the only elements to be considered, for there are many others affecting the number of oscillations which a needle makes. Every different thermometric, barometric and hygrometric state of the atmosphere causes a different resistance to the oscillation of the needle; arising from the fluctuation in dimension of the needle itself, and by the varying nature and density of the medium it vibrates in.

Having determined, that magnetic intensity decreases, in ascending above the surface, it might be expected that the oscillations of the needle would also diminish in number, with the altitude. It will be observed, however, that the density of the atmosphere decreases in ascending, and thus removes an obstacle to freedom of action, which *may* more than compensate the diminishing power of the calorific flow. Philosophers, however, are not agreed with respect to the facts of the case.

It appears that the dipping needle, when moving in a vertical plane, makes a fewer number of oscillations in the middle latitudes than in the lower, and yet increases the number again in the higher latitudes. This anomalous phenomenon seems capable of being solved in the following manner.

At the magnetic equator, the needle being horizontal, the horizon bisects the angles of oscillation. So that on being diverted, there are two co-operative forces in action to bring the instrument to the horizon again, viz, the force of gravity, and the power of the calorific flow, which is exerted there in a horizontal direction.

On advancing from the magnetic equator, the needle inclines to the earth, when in a state of rest, taking the direction of the local dip of the calorific current. When diverted, therefore, the horizon no longer bisects the angles of oscillation, wherefore in those portions of each arc of oscillation, which are performed above the horizon, the two powers co-operate to bring it to the horizon. On descending below the horizon, (that is below the physical balance,) the power of gravity is counter to that of the calorific current, the former tending to raise the instrument, the latter to depress it; its momentum consequently receives an additional check at this portion of every oscillation from this cause. Below the line of the calorific dip the two powers co-operate again, both in the continuance of its descent and its subsequent ascent. On rising above the line of the calorific dip, till it reaches the horizon, the two powers are again at variance, thus causing a period of retardation in its ascent, and, on rising above the horizon, they are again in unison.

The inevitable consequence of this variance of powers, which we have noticed, is to check the oscillations of the instrument, and render them slower.

After passing certain high latitudes, however, its oscillations are found to increase again. The reason is obvious from the foregoing: the variance of powers being destroyed, as the instrument approaches another physical balance, viz. the vertical position;. when the conditions governing its oscillations are the same as at the magnetic equator.

AN ANALYSIS
OF
TERRESTRIAL MAGNETISM.

PART II.

Having shown, in the preceding division of this treatise, the coincidence of the general calorific and magnetic currents of our globe, and, we trust, satisfactorily, we shall now endeavor to explain the manner in which caloric acts to produce the phenomenon of magnetism.

Magnetism has always been considered as the mysterious and inexplicable offspring of some mysterious and inexplicable cause; and many have been the hypotheses advanced to account for the various phenomena attending it. We shall, however, pass them over, and proceed to investigate its nature; premising, that no theory has ever been advanced before, capable of solving magnetic phenomena, and much less a known natural cause. Physicians say, that when the nature of the disease is known, the cure is half performed; and, so when the cause of magnetism is known, it may not be deemed too presumptuous to endeavor to trace the mode of its operation.

In the first place, we shall define what we conceive "magnetism" to be, as also wherein "polarity" consists; including in this latter term the "dip," as the two together constitute the course of the calorific currents and the direction of the needle; and then substantiate our positions as we may.

MAGNETISM—Motion produced by a current or currents of vertically converging elementary caloric in certain bodies, *in consequence of their resisting the free change of identity of their absolute volume of caloric*, and thus opposing the free passage of the general equatorial flow through them, in its passage toward the points of greatest terrestrial deficiency of caloric.

POLARITY—The property which a centrally poised prismatic blade, of those bodies which are subject to the magnetic motion, has of turning in the direction of the calorific or magnetic current, with one end in preference to the other pointing toward the destination of the flow, *caused by the uniform set of the molecular angles of the surface of those bodies from this end toward that which points in the direction from which the flow comes.*

Though, at a given temperature, any given substance has a given absolute volume of caloric, yet it does not follow that that very caloric is eternally imprisoned in that substance; any more than it would follow that, because a river should denote the same depth of water to-day that it denoted yesterday, therefore to-day's water is identical with yesterday's, at the same spot; or that, because the barometer should indicate the same atmospheric pressure to-day that it did yesterday, therefore the superincumbent atmosphere of to-day is identical with that of yesterday. On the contrary, the *identity of the caloric of the atmosphere, at least, is perpetually changing*; and it may be laid down as a physical axiom, that "there is no such thing as a perfect stagnation in nature."

To prove the change of identity in the caloric of the atmosphere every instant, and at a fixed temperature, we need only look at the means by which evaporation is carried on: it is by the descent of the atmospheric caloric of the lower stratum, and its subsequent combination with the superficial moisture of the earth. Now, as a given proportion of the absolute volume of caloric is thus abstracted from the lower strata, their sensible temperature would be perpetually reducing, were it not for the descent of an equal volume from above. Thus, the lower strata have parted with a portion of their original caloric, and received an equal volume, by which means their temperature remains the same; but the *identity* of their absolute calorific volume is changed. Moreover, we have before proved, that there is a general calorific current from the line of greatest terrestrial superabundance to the points of greatest terrestrial deficiency; and this current must perpetually change the identity of the atmospheric caloric, as it could not proceed in its course unless it displaced the volume in advance of it, not to mention the change of position suffered by the particles of the current itself.

So also of bodies existing in the atmosphere, we can prove that there is a perpetual change of identity in their absolute caloric going on. Every reduction of atmospheric temperature is attended with a reduction of temperature in the bodies in contact with it; therefore, part of the absolute volume existing in any body, previous to the reduction taking place, is then lost to that body, and hurries poleward with the general equatorial flow, through the atmosphere. An increase of atmospheric temperature afterward takes place, equal to the former reduction, and the body under review rises also to the temperature of the surrounding medium, by the introsusception of an absolute volume of caloric equal to that it emitted on the reduction of its temperature. Thus, on a reduction of temperature, the identity of the remaining absolute volume of caloric may be the same, (considered for an instant): and, as the volume given out is hurried onward by the general equatorial flow, an increase of temperature, or absolute volume of caloric, in any body, is caused by the introsusception of another volume; when the identity of the absolute volume, as compared with that of the same body at the same temperature previous to the reduction, is partially destroyed, and by similar successive operations would be so entirely.

These operations are also another proof that a change of calorific identity is perpetually taking place in the atmosphere; for the absolute volume acquired by any body, on an increase of temperature, is transmitted to it from the atmosphere, and that emitted by it, on a reduction of temperature, is passed from it into the atmosphere; in either case the identity of the calorific volume in the surrounding medium is either totally or partially destroyed.

As the alternations of temperature change the identity of the absolute caloric of bodies, and as this is effected by the reception and emission of caloric, transmitted to them and by them through the surrounding atmosphere, proving that all substances are permeable to caloric, it is not assuming too much to imagine that *all substances may, like atmospheric air, change the identity of their absolute caloric, while the temperature remains uniform.*

For all substances are more or less permeable to caloric, and always subject to the action of the general equatorial flow, *in transitu*, to the points of greatest terrestrial deficiency of caloric. Part of this general flow impinging on their external surfaces, will enter between the interstices of their molecules and of their constituent atoms, and force out a volume equal to that which entered. That this is so, is plain from the fact, that the sensible temperature of any body suspended in the atmosphere, whatever may be its capacity for caloric, is the same as that of the surrounding medium; which could not be the case, unless it perpetually changed the identity of its absolute caloric. For if we assume, for the sake of argument, that the identity of the absolute volume of any given body, at any given atmospheric temperature, remains unaltered, that is, that no particle of it is emitted while the atmospheric temperature remains constant; then must the sensible temperature of a body, exposed to the action of the general flow, rise continually above the sensible temperature of the ambient air, until it arrive at the point of elementary separation of its parts.

For, as the body under consideration has the capacity of retaining a larger absolute volume, and as the actual absolute volume is in this case supposed quiescent, and as the momentum of the equatorial flow forms a compressing power upon the imprisoned corporeal volume; a continual condensation of the identical absolute volume, and the addition of another absolute volume, subject also to subsequent condensation, must take place; that is, the body would continually increase in absolute calorific volume, and hence have its sensible temperature continually augmented, until it arrived at the point of molecular or elementary dissolution.

But this is not the case; wherefore, *all bodies are perpetually changing the identity of their absolute volume of caloric.*

The period of complete change of identity will depend on the momentum of the equatorial flow, the ratio of its absolute volume to that of the body under consideration, and the degree of calorific permeability, or transmission, which the body possesses.

Thus a sponge, saturated with water, which may be considered its absolute volume of water, when exposed to the action of a stream of water, will remain saturated, but be perpetually changing the identity of its absolute volume, as may be proved by a colored saturation; the time of complete change depending on the force of the current, on the texture or compression of the sponge, allowing it free or difficult transmission, and on the absolute volume of water required to saturate it.

When, therefore, a prismatic bar of any solid substance is balanced delicately on a fulcrum, the equatorial flow of caloric has only to overcome its inertia and friction to cause it to take its own course, that is, to dip and polarize, or, in other words, to exhibit phenomena which we call magnetic.

If, then, we could conceive a solid body perfectly permeable to caloric, that is, changing the identity of its absolute caloric as fast as the equatorial flow supplied an equal absolute volume, or, in other words, allowing an uninterrupted equatorial flow *through its substance*, that body would be perfectly unmagnetic, that is, uninfluenced in its direction by the power of the equatorial flow. But this is inconceivable; because caloric cannot penetrate the elementary atoms of bodies, (for this is to suppose them further divisible by mechanical agency), but only through and between their molecules or between their constituent atoms; and, as the atmosphere, (whatever may be its local constituents), is the vehicle of calorific transmission to all bodies, and, as the elementary atoms of solid bodies approximate nearer than those of atmospheric air; therefore, all solid bodies oppose a greater resistance to the passage of the equatorial flow than do those of a gaseous nature; and, consequently, all solid substances are magnetic in degree, as proved by the experiments of Coulomb, before the French Institute; that is, as we should define it, they are subject in degree to the mechanical force of the equatorial flow.

If, on the contrary, we could conceive a substance perfectly impenetrable to the equatorial flow, that is, retaining its identical absolute caloric *in perpetuo*, this would be the best magnet we could obtain; but this is equally inconceivable as the former case; for it is to conceive a body incapable of changing its sensible temperature, which is certainly not the case. *Wherefore, all bodies are magnetic in degree*, that is, *are all subject in degree to the directive force of the equatorial flow.*

It remains, then, to find a substance possessing such small specific gravity, and of such a degree of reduced calorific permeability or transmission, as shall allow the restrained equatorial flow to show its mechanical effects in a sensible manner, by turning a balanced prism of it in its own direction, in order to expose the least surface of resistance to its progress; that is, to cause it to dip and polarize. The nature of the pole, or leading end, we shall determine hereafter.

Such a substance is iron, though weakly in its pure state. Of what part of its absolute caloric it changes the identity in a given time by the action of the equatorial flow, we do not yet know; but reason will show us it must change some proportion. It does not seem improbable that the freedom of the change of identity is connected with the facility of calorific transmission: the greater the facility of transmission, the greater the freedom with which the change of identity in the absolute caloric of a body takes place, and, consequently, the less it is subject to the mechanical force of the equatorial flow; and *vice versa.* Now, according to Dr. Ingenhauz, (as cited by Dr, Ure,) the following metals transmit caloric in the order in which they are named:

1. Silver.
2. Gold.
3. Copper and Tin, (nearly equal.)
4. Platinum, Iron, Steel, Lead, much inferior to the others.

Thus, with the exception of lead, iron is the lowest in the scale of transmission, and, when converted into steel, its power of transmission is further deteriorated. If, then, less of the caloric of the equatorial flow be transmitted, in the same time, through iron than through the metals previously named, more must pass externally; and, consequently, the flow must have a greater mechanical effect on iron than on the others; and a greater effect on steel than on iron.

We are aware it may be asked, why then does not lead also polarize? We reply, that the equatorial flow has another opposing element to overcome, such, that if iron be barely subject to its power, lead will not be affected: viz. the greater inertia of lead as compared with that of iron; the specific gravity of lead being 11.35, while that of iron is only 7.788; which probably more than counterbalances the increase of power gained by the equatorial flow over lead, in consequence of its diminished power of transmission. But, lest this reasoning alone should be deemed inconclusive, we will view it in another light.

As a principle, it seems perfectly rational to suppose, that if the absolute caloric of bodies changes by the action of the equatorial flow, a body possessing a *large* specific volume of caloric will oppose a greater resistance to the change of identity in its absolute caloric, than a body possessing a smaller specific volume, under the same circumstances. We shall, therefore, compare the specific heats and specific gravities of the two metals, deducing therefrom the comparative power of the equatorial flow over each.

The specific caloric of iron is 0.1190, (that of water being unity,) and that of lead 0.0293; wherefore, the mechanical action of the equatorial flow upon iron, is to its action upon lead, as respects the change of identity only, as 4 to 1 in round numbers; but the specific gravity of iron is 7.788, while that of lead is 11.35; wherefore, the mechanical action of the flow upon iron is to its action upon lead, as respects the inertia of the bodies, in inverse ratio with their specific gravities, or as 11 to 7 in round numbers. So that the equatorial flow clearly exercises more mechanical power over a needle of iron than over one of lead.

Yet the iron will not move to, or obey the flow, because the power of the flow is not yet sufficient to move it, unless a magnet be applied; but this cannot be understood yet, until we have explained what a magnet is. We shall, however, solve this phenomenon, when we come to investigate the nature of magnetic attractions and repulsions. Suffice it here to call this state of iron *magnetic*, that is, *attracted by a magnet.* It will not *polarize* for the reason assigned above.

If, now, by any chemical means, we can increase its *specific*, and consequently, its *absolute* caloric, *without increasing its specific gravity* at the same time, we increase the difficulty with which the change of calorific identity is effected, and consequently, the mechanical power of the equatorial flow upon it; and, if we can but accomplish the diminution of its specific gravity at the same time, we increase the mechanical power of the flow upon it materially. The chemical combination of carbon with iron effects both these desiderata; for, according to Godolin, as cited by Dr. Ure, the specific caloric of iron is 0.1190, while that of steel, the carburet of iron, in its soft state, is 0.1200; showing an augmentation of its specific caloric; and the specific gravity of iron is 7.788, while that of soft steel is 7.738, according to Hawkesbie, showing a diminution of specific gravity. According to M. Thenard, also, the specific gravity of steel is below that of iron.

It is to be observed, that iron in this form, will obey the flow after the touch of a magnet, turning north and south, or polarizing; but it does not seem to retain this property long, when laid indifferently in any position, owing to the facility with which the molecular structure of the surface is altered by the action of the equatorial flow, as we shall show; when we come to treat on the subject of polarity.

If, when highly heated, we plunge the steel into cold water, it becomes hard;* and we again alter its nature chemically, increasing its specific caloric, and diminishing its specific gravity; for the specific caloric of hard steel is, according to Godolin, 0.1230; and its specific gravity is 7.704, according to Hawkesbie. In this state, likewise, it will obey the equatorial flow and polarize, after the touch of a magnet, being in reality the best needle we can procure. It will, also, retain the property of polarity, when laid indifferently in any position, for very long periods of time; which we shall hereafter show is dependent on the greater immobility of its superficial molecules.

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* We may remark here, incidentally, that we consider the difference between hard and soft steel to arise solely from the combination of a minute portion of hydrogen with the latter, the specific caloric of which gas is greater than that of any known substance. For, the constituents of water are only oxygen and hydrogen; and, as the combination of oxygen with steel will oxidize its surface, and as steel may be hardened under water without oxidation, hydrogen is the only substance it can absorb; which is rendered more probable by the fact that carbon and hydrogen will unite.

This view of the subject is also borne out by the only two other metals which are magnetic, in the ordinary sense of the word, viz. nickel and cobalt. Nickel is so magnetic that, after the touch, it will even polarize. Its specific gravity, 8.4, though somewhat above that of iron, 7.788, is far below that of lead, 11.35; while its specific caloric, 0.1035, is not materially below that of iron, 0.1190, and much above that of lead, 0.0293; wherefore, the equatorial flow has much more power over it than over lead, though somewhat less than it has over iron. The cause of its polarizing will be understood, when we have explained the nature of the polarity of steel. Cobalt is also slightly magnetic, but will not polarize. Its specific gravity is 8.6, which is nearly one-eighth more than that of iron, thus causing a great additional obstruction to the mechanical effort of the flow, but its specific caloric is accordingly 0.1498, much above that of iron or steel, thus causing a greater resistance to the change of calorific identity than iron or steel. Thus, though it loses on the one hand, it gains on the other, and motion or magnetism is the consequence. The reason it does not acquire the property of polarity will be explained hereafter.

In the same way, if we look to the specific gravity and specific caloric of the other metals, we find a wonderful coincidence with the principle we advance; showing that, if mere iron be magnetic, but not susceptible of magnetic directive influence, they can be so but in an inferior degree. We here subjoin a table of the specific heats and specific gravities of the principal metals, arranging them in the order of their specific gravities, with the exception of iron, which we place first, for the convenience of comparison.

A TABLE OF THE SPECIFIC GRAVITIES AND SPECIFIC HEATS OF THE PRINCIPAL METALS.

	Sp. Gr.	Sp. Cal.
Iron, ...	7.788	0.1190
Steel, (soft)	7.738	0.1200
Do. (hard)	7.704	0.1230
Platinum, .	21.47	0.0314
Gold, ...	19.30	0.0298
Lead, . . .	11.35	0.0293
Silver, . . .	10.45	0.0557
Bismuth, . .	9.86	0.0288
Copper, . .	8.9	0.0949
Cobalt, . . .	8.6	0.1498
Nickel, . . .	8.4	0.1035
Tin, ...	7.29	0.0514
Zinc, ...	6.9	0.0927

The specific gravity of zinc being 6.9, something considerably below that of iron, might give rise to a suspicion that it should be magnetic; but its specific caloric, 0.0927, being less than that of iron by 0.0263, will destroy the advantage gained by the reduction of specific gravity, as compared with that of iron: for, the reduction of specific gravity is, in round numbers, about one-seventh; while the reduction of specific caloric is about one-fifth.

An expert algebraic analyst would be able to give the effective force of the flow, in all the cases above cited, and, we have no doubt that they would be found to be below that of the flow on iron; and that the effective force of the flow on iron would be less than that on soft steel; and on this latter less than on hard steel.

The volume of carbon absorbed by iron, during the process of its conversion into steel, is very various: as a mean, we may say, that it absorbs one seventy-second part of its weight to form good steel; that is, seventy-two pounds of iron will make seventy-three pounds of steel. Too large a dose will convert it into plumbago, which is not magnetic in the ordinary sense of the word. There are, also, other substances, whose combination with iron renders it magnetic: sulphur and phosphorus are of this class: and, it will be observed, that these combinations increase the hardness of the metal, as is the case with carbon. With respect to the specific gravities and specific heats of the resulting compounds, we have no clue: yet, we presume, they are specifically lighter, and should infer that they are of decidedly greater specific caloric, from the circumstance that the specific caloric of both the combinants is very considerably above that of iron.

Hitherto we have been considering that part of the equatorial flow which enters the body under consideration; it now becomes our duty to consider the nature and destination of that portion which is arrested in its course as it impinges against the body.

If we consider the nature of a current of water, and its subsequent course when it is arrested in its progress by impinging upon the surface of any body, we shall find, that it flows round the body on all sides, displacing that which was in contact before, and thus forms a local diverting current upon the general one. This, then, on the supposition of the material nature of heat, will be the destination of that volume of the equatorial flow, rejected by any body; and, we shall show hereafter, that this is amply sufficient to account for magnetic attractions and repulsions, if taken in connexion with the cause of the polarity of bodies not yet explained.

As a small compression of the atmospheric volume of caloric must take place in the neighborhood of any body, we think it probable that a very sensible thermometer might detect a minute difference of temperature in the immediate vicinity of every substance; differing, however, in the neighborhood of different substances, and being greatest in the neighborhood of steel, as well as extending to a greater distance.

If a mode of action peculiar to caloric be sought for, we should say it acted in an electrical manner; but we can conceive no difference in this respect from an aqueous flow: the laws being the same, depending only on inequality of distribution, (analogous to inequality of level in the case of water,) and the permeability or impermeability of the opposing substance. We are the rather inclined to explain its action through this modification of caloric, because electricity exercises attractions and repulsions, and will form magnets and reverse their poles at pleasure, performing most of the wonders of a magnet. We shall hereafter show, that, as the agent is external, its effects are produced by a mechanical exertion of power on the surface of the needle.

It is well known, by the hollow sphere of Coulomb, that electricity is collected on the external surfaces of good conductors, and that it is not diffused throughout their mass; by consequence, its action is external; and in the case of its transit to another conductor, it evidently affects its surface first. This is further confirmed by the fact, that lightning frequently solders the links of a chain together, in which case their surfaces only have undergone fusion; proving that the fluid, or the far greater part of it, passed externally and not internally.

In the act of escaping from any solid body which is isolated, electricity, (now generally acknowledged as a modification of caloric), exerts a mechanical force upon it, which is proved by many experiments. To pass over the well known destructive effects of lightning, we shall select the common one of the balanced S wire, as being nearest in form to the instruments we are reasoning on. It revolves as long as the fluid is given off, and with a velocity proportioned to the supply. It may be objected to this, that all substances giving off electricity, under the same circumstances, are affected in a similar manner. We admit it; but conceive they are affected in different degrees; and, therefore, a slight effort will disturb the more sensible; and we have shown that steel is more sensible to the impulse of caloric than the other metals.

As the caloric of electricity acts mechanically upon bodies, so also may the caloric of magnetism. We, therefore, consider the dip and direction, or the polarity of the magnetic needle, as the effect of the mechanical power of that absolute volume of the equatorial flow denied the privilege of transmission through the obstacles it meets, and, that the leading end, or pole, is determined by the particular molecular arrangement of the surface of the needle.

As we have considered the action of caloric as external, in order to solve the nature of the leading end, we have only to consider the nature of the surface on which the action takes place. Before we proceed, however, we must ask as a postulate,

That the molecules of iron and steel are not truly globular.

We cannot pretend to give the form of the ultimate particles of steel or iron; but any form, having axes of different lengths, or any angular form presenting a flat, or concave, or a convex surface, to the action of the equatorial flow, will equally solve the problem. We are aware that we found our theory of the polar ends of the needle upon an hypothesis; but as the only form that will not solve it is the true sphere, and as this is but one out of the million-and-one conceivable forms in nature that will solve the problem, the chances are a million to one in favor of our hypothesis, which amounts almost to a certainty.

But to view the reasonableness of our postulate in another light.—Suppose that the ultimate atoms of iron were globular, it is next to impossible that those of steel should be; for, as the combination of carbon with iron takes place to an almost indefinite extent, that is, that an indefinite number of atoms of carbon may aggregate themselves round a single atom of iron, the molecules of all the possible resulting carburets cannot be similar in form, or, in other words, the ultimate particles of all kinds of steel cannot be globular. But it is unnecessary to multiply our observations on this subject: it is too evident.

In the following pages we shall select the triangular form as that of the molecule, for the sake of greater perspicuity.

As a preliminary remark, we here make the observation, that the friction of one metallic body over another causes a change in the disposition of the external molecules of one or both the pieces experimented on, as is evident by the polish which succeeds the operation, and which is improved by every subsequent stroke.

There is a mechanical alteration of the surface, which might result from passing a magnet over it; that of raising the angles of the superficial molecules, and thus forming a very fine *beard*, (if we may be allowed the term), setting back *toward* one end, and thus opposing a mechanical resistance to the equatorial flow in the direction of the opposite end. The serrated blade of a saw will represent a sectional view of our conception. This arrangement of the molecules will inevitably cause a balanced prism to obey the flow, with one end or pole turning to the point of calorific destination in preference to the other, if it can be shown that the change of identity in the absolute caloric of the molecules is effected with greater difficulty than that of the mass. The following considerations will show that this must necessarily be the case. A piece of iron may be heated so that at length it melts: this does not destroy the molecules, but only the cohesion which exists among them: therefore, it requires a much greater absolute volume of caloric to destroy the molecules themselves, (if, indeed, the metals are compound bodies, which is questionable): consequently, the action of any given flow of caloric will effect the change of identity of the caloric of molecular cohesion in a quicker ratio than that of the caloric of atomic cohesion; and if the molecules of the metals are undecompounded simple atoms, the flow will not affect the molecules at all in this respect; for matter cannot penetrate matter.

We therefore propose to show here, that the particular arrangement of the external molecules is capable of solving the phenomena of magnetic polarity, and also of magnetic attraction and repulsion.

If we take a blade of steel, whose two ends we shall denominate *a* and *b*, (as in Plate II. Fig. 1.) and pass the south pole of a magnet from *a* to *b*, it will become a polarizing magnet also: the end *a*, which was first touched, being its south pole, that is, pointing south; and the end *b*, which was last touched, being its north pole, that is, pointing north. If we afterwards pass the south pole of the magnet from *b* to *a*, the poles will be reversed; that is, *b* will become a south pole, and *a* a north pole. But if we make this last stroke with only a certain intensity of pressure, we shall depolarize the blade, or render it simply magnetic; that is, attracted by either pole of a magnet.

Now, on the supposition that the angles of the molecules are raised above the primitive surface by the influence of the pressure, and granting the existence and mechanical effect of the equatorial flow, all this may be easily explained; especially as we know there is no inherent virtue in the magnet itself; for magnets may be made from unmagnetized iron and steel alone.

If the passage of the south pole from *a* to *b*, raises the angles of the superficial molecules which look toward *a*, then if the blade be centrally poised, and obey the flow of caloric, it must turn with its end *b* toward the point of destination of the flow; and as this is toward the north in this hemisphere, it points north, and is called the north pole of the needle. If now we take the magnet and pass its south pole from *b* to *a*, the effect will be to depress the angles before raised, and elevate the angles of the same or of other molecules looking toward *a*, when the resistance to the flow is in a direction toward *a*, and the needle turns round with its end *a* toward the north: the poles are now said to be reversed; that is, as we should explain it, the arrangement of the molecular angles, and consequently the leading end of the blade, is reversed. If the magnet be passed from *b* to *a*, with only a certain intensity of pressure, it will merely lay the beard even, without raising the opposite angles of the molecules; thus, no mechanical resistance being opposed to the external flow, which should cause one end to lead in preference to the other, the needle is merely magnetic, that is, attracted by either pole of a magnet. This is the view we have of the nature of magnetic polarity.

If the north pole of the magnet be passed from the south pole *a* to *b*, (as in Fig. 2.) the poles will be reversed, *b* becoming the south pole, and *a* the north pole. The reason is, that the molecular angles of the north pole, in passing over the blade, depress the elevated angles and raise the opposite ones; the effect being in reality the same as that explaining the action of the south pole of a magnet passing from the north pole of the blade to the south pole; for the angles of a north pole are set the contrary way to those of a south pole, (with respect to their position when moving over the blade), and either must raise the contrary angles in its passage.

If the impression of the teeth of a saw be left on a piece of wood, a fac simile will be produced; but the teeth (analogous here to the molecular angles we suppose) will be found to incline the contrary way with respect to those of the saw which produced them; that is, the teeth of the saw set from the handle to the point; whereas the force exerted by the hand to produce the fac simile will cause its teeth to incline toward the hand. The same effect would be produced by a point in movement raising them successively.

These views are further confirmed by the following experiments:—If we take a needle of hardened steel, supposing it unmagnetized, (or rather, as it is magnetic, impolarized,) and pass either the north or south pole of a magnet from the centre, *c*, to each end, *a* and *b*, (*Fig.* 3.) it will not polarize when placed magnetically east and west. For the molecular angles being raised by the same pole of the magnet passed in contrary directions, will all point from or to the centre, and consequently when subjected to the flow in this position, will not obey it, because both ends are equally and similarly affected. If, also, the needle have a north and a south pole, and the north pole of a magnet be passed from the south pole, (or *vice versa*, the south pole of a magnet from the north pole), to the centre, *c*, the blade will not polarize when placed east and west; for the effect, as respects the molecular disposition, is identical with that of the former experiment.

We have not absolutely tried this experiment: but infer the consequence, however, from a variation of the experiment, which we shall soon mention.

Our aim is to show, that it is merely the mechanical resistance afforded to the equatorial flow by the set or position of the angles of the molecules with respect to *one* end of the needle, that causes it to point north and south. The mere fact that the same pole of a magnet will make a north and a south pole at the same stroke, when passed from end to end of a blade of steel, is of itself sufficient to convince us that it is not the effect of any virtue or fluid residing in the magnet itself; for if this virtue or fluid was of one pole or hemisphere, how could it impart another virtue to the blade? The hypothesis, also, of a peculiar magnetic fluid, circulating from end to end of the magnet, is perfectly untenable; because its circulation then depends on the form of the body which encloses it, without reference to its position: wherefore, it could not turn it in any particular direction. If, on the contrary, it be maintained that this fluid is in motion from the equator to the poles, and passing through the needle, carries it with it; then we have shown that caloric answers to these conditions, and consequently there is no need to advance an hypothesis where there is an active cause in existence.

We shall now show that the external action of the general equatorial flow upon the exposed angles of the superficial molecules is sufficient to account for magnetic phenomena.

Electricity, when accumulated in sufficient quantities on the surfaces of metallic bodies, will fuse them, as proved by the passage of lightning and by numerous electrical experiments. When accumulated therefore in smaller quantities, it will exercise a proportionate influence on the surface only in the direction of its passage. Now, on passing a current of electricity through (over) a blade of steel, the end which receives becomes a south pole, and that which gives off becomes a north pole, in the northern hemisphere, (the reverse probably in the southern): in other words, upon the hypothesis we have advanced, in proceeding over the external molecules, it raised their angles toward the receiving end, because it took them first, causing a resistance toward the opposite end, which being now subject to the directive influence of the general flow, points to its destination, and is hence called the north pole of the needle. Apply the north pole to the current, and the opposite angles of each molecule will be raised, and the poles are reversed: and, doubtless, were a delicate experiment made, causing only a certain alteration of the molecular disposition, (laying them flush), the blade would be depolarized, as in operating upon it with a magnet.

It is well known that lightning exercises a material influence over magnets; that it will reverse their poles, destroy their polarity, restore it when lost, and cause steel to polarize that did not before. The reason is the same as that we have advanced for the action of electricity and of magnets.

The only case of the reversion of the poles of the compass by lightning that we have been able to trace by personal inquiry, occurred in the month of July, 1832. Our friend Capt. Budd, of the brig Dromo, bound from New York to Curacoa, was struck, off the Bermudas, and his compass reversed. He informs us that the stroke came from the W. N. W. Although the angle at which the electric current struck the needle from the northward was small, its volume and velocity more than counterbalanced this loss of power, and reversed the set of the molecular angles. Had the lightning struck it from the southward, it would not have affected it otherwise, perhaps, than by improving its activity: for, as lightning may pass over the whole surface, it will affect all the molecules; whereas, it is possible that the action of a magnet, by the application of which a compass is usually made, may not affect all, in consequence of irregularities of the surface. Had the stroke come from the magnetic east or west, it would most probably have left it unaffected, or depolarized it completely, by laying the set of the molecules east or west.

We have no doubt, that in all cases of the reversion of the poles in the northern hemisphere, the electric stream has come from the northerly points of the compass, and in the southern hemisphere from the southerly points.

As lightning always traverses the length of a piece of metal, this will explain the frequency with which iron rods polarize after being struck.

The same reasoning applies with equal force to the spontaneous acquisition and destruction of magnetic properties. A bar of steel, laid in or near the magnetic or calorific meridian, acquires magnetic polarity in the course of time. The reason we give is as follows: The continual equatorial flow of caloric toward it, as it changes the identity of its absolute caloric, enters at the southern angles of the superficial molecules, and, raising them in the course of time, causes a resistance to the future flow: at the same time, the molecules, when once raised, present an increased facility for the mechanical action of the flow, by an extension of the surface acted on, and a diminution of its obliquity, till arrived at the greatest elevation they are capable of, when the polarizing virtue of the bar is in its prime.

The usual precautionary measure taken to preserve the virtue of a magnet, by placing it in the magnetic meridian, with its north pole to the north, is also proof in favor of our hypothesis. If we lay it in the meridian for a long time, with its north pole turned to the south, its magnetic properties will be impaired: for the angles of the molecules will be gradually smoothed down by the action of the equatorial flow, and its property of magnetic polarity is gradually destroyed as they return to their primitive position, till at length it is simply magnetic, that is, attracted by either pole of a magnet; when it is reduced to the state of an unmagnetized blade of steel. If it be kept longer in this position, it will resume its magnetic virtues, like any other unmagnetized blade of steel; the end pointing north becoming the north pole, and the opposite the south pole; by reason of the opposite angles of the molecules being raised toward the south; or, as the usual expression is, with its poles reversed.

There is also another experiment, which may almost be considered conclusive in favor of the molecular hypothesis. Hold an unmagnetized bar of steel in or near the direction of the dip, and give it a smart blow with an unmagnetized hammer, either below or above, or let it fall perpendicularly upon a piece of iron or other hard substance, such as a hearth, and it instantly becomes a polarizing magnet, of which the lower end is invariably the north pole in this hemisphere.

Now, a blow on either end jars the whole bar, and causes it to ring, which is produced by the vibratory motion of the external molecules certainly, turning to and fro on their axes. If the blow be given on the under end of the bar, (*a*, Fig. 4.) the molecules turning on their axes toward the blow, present their upper angles to the action of the general flow, which, interposing between them and their neighbors, prevent their complete return, thus causing the lower end to be the leading end or north pole; and a few repetitions of the blow will cause their highest elevation, when the blade acquires its utmost property of polarity; that is, when suspended, will traverse more and more briskly with every repetition of the blow, till it travels as briskly as it ever will. When the blade receives the blow on its upper end, (*b*, Fig. 5.) the molecules turning to the blow, that end for an instant becomes the leading pole; but on their revulsion downward, the flow operates the same as in the case of giving the blow below, and the lower end is consequently, in this case also, the north or leading pole of the blade.

The same effects will not take place, perhaps, at right angles with the meridian, or only in a less degree, because the molecules may return to their original places with the revulsion, for want of the proper action of the equatorial flow. It is evident, that, as the molecular angles of the blade are raised toward one of its ends, and as the direction of the flow is not against, but between the molecules, it passes on without detaining them.

Twisting a magnetized wire, also, will reverse, destroy, or disorder its polarity in different parts; and torsion evidently alters the arrangement of the external molecules.

Rust, also, destroys the virtue of a magnet, and this is always a superficial action, and destroys, as all know, the surface, that is, the superficial molecules.

We took a blade of steel, and touched it with a magnet, so that it would support itself when attracted at one pole by a piece of soft iron; then put it into diluted nitric acid for a few minutes: on taking it out, and trying it with the same piece of iron, it could not be raised above an angle of 30° or so, without detaching it from the iron. On examining the blade, we found that there were bright spots scattered over it, and raised above the common surface, being portions of steel untouched by the acid from some cause or other; and, beyond a doubt, it was these untouched surfaces that caused the existence of the diminished magnetic power: had they been eaten away also, it would most probably have been entirely destroyed.

We took a blade of steel, (watch spring), and passing the north pole of a magnet from the centre to each end, we placed it on water, and found that the north pole of the magnet attracted each end of the blade, and that the south pole repelled them; proving them to be real south poles. Nevertheless, upon allowing the blade to settle, to our surprise, and totally contrary to our expectations, we found it polarize. At first, we were confounded, and could not reconcile this to the theory; but the application of the south pole of a magnet toward the centre of the blade soon cleared up the difficulty; for we found invariably that the pole never coincided with the centre of the blade, but divided it into two unequal halves, of which the smaller always pointed north: the reason then became evident. The longer half of the blade had a north and a south pole; that is, the beard set uniformly from the north to the south pole. Consequently, the equatorial flow acting more powerfully on the greater than on the smaller half, it forms a polarizing magnet, its centre being the fulcrum; and the smaller end being overpowered, is a mere negation.

Fig. 6 shows the state of the blade as to the set of its molecules, after being magnetized as above. It should be borne in mind, that in the northern hemisphere the beard of a true magnet, (one touched with one pole from end to end), inclines from one end (its north pole), to the other, (its south pole); and in the southern hemisphere, of course, the reverse.

a, NP is a polarizing magnet, *a* being a true south pole, and NP a true north pole: *b*, NP is also a polarizing magnet, *b* being a true south pole, and NP its true north pole. But the magnet *a*, NP is greater than the magnet *b*, NP; and, as the two are united with the same axis common to both, the larger magnet governs the direction of the whole blade. So that NP is the north pole of the whole bar, *a* its south pole, and *f* (the bisection of the larger magnet) is the magnetical fulcrum on which the whole bar turns theoretically in the act of polarizing. But *b* being in the same line with NP, and preceding it, may be considered, for simplicity's sake, a true north pole. It is plain, the equatorial flow has more power over the larger than over the smaller half. If, by repeated trial, we can bring NP to coincide with *c*, the centre of the blade, (supposing the surface as well as the weights of each half equal), the blade will not polarize, when placed east and west, as we have ourselves experienced, on a modification of the experiment, with two blades. But this is almost impossible, for the moment the magnet alters the arrangement of the molecules in advance of the point of contact, their cohesion with those beyond, influences them also, and thus causes the same molecular arrangement to extend beyond the point intended.

The truth of this reasoning will be evident from the following reverse of the above experiment. Pass the south pole of the magnet from any point that is not the centre to each end of the blade: it will be found that the south pole of a magnet will attract, and the north pole repel, each end of the blade; proving them both north poles. Yet the blade will polarize; but, contrary to the effect in the former experiment, it will be found that the smaller half will invariably turn south, and the larger half north. The longer half of the blade has a north and south pole: consequently, the equatorial flow acting more powerfully on the greater than on the smaller half, it forms a polarizing magnet, governing the direction of the whole blade, its centre being the magnetic fulcrum, and the smaller end being overpowered, is a mere negation.

Fig. 7 shows the state of the blade as to the set of the molecules: *a b* may be considered a compound magnet, *a* and *b* being two north poles, and SP a south pole. The magnet *b*, SP, being larger than the magnet *a*, SP, will govern the direction of the whole blade, and, as *b* is its north pole, that is, as the molecular angles set from *b* toward SP, the resistance of the bar to the equatorial flow is toward *b*, which is, therefore, the leading end or north pole of the bar in this hemisphere, (though it would evidently be the south pole in the southern); and *f*, the point of bisection of the greater or governing magnet, is the magnetic centre or fulcrum on which (theoretically) the whole bar turns: *a*, SP may be considered a mere negation; or, as *a* is in the same line with SP, it may be considered a virtual south pole.

It is to be observed, that in trying experiments on water, if the surface be even or convex, the blade will move forward, after settling along the line of the magnetic meridian or paropsis. If the surface be concave, it will move to the centre of the surface, polarize and be stationary. Its motion northward is probably owing to two causes, a direct and a consequential; the mechanical action of the equatorial flow propels it, as it is not confined by a mechanical fulcrum, and this is assisted by the dip causing the north pole to be depressed below the south pole, when its inclination carries it forward. Thus a shell dropped into the water edgewise will move in the plane of its inclination. It is stationary on a concave surface, because it cannot move up an inclined plane.

We took two blades of steel and magnetized them for a true north and south pole each, and put the two north poles into a common centre, so as to form one needle whose extremities were two south poles. When balanced, it polarized north and south, but it was indifferent which end led; whichever was laid north of east or west immediately moved north, but very feebly. In this case, being in the northern hemisphere, and the molecular angles of each blade turned from the common centre toward each end, the resistance is then from either end toward the common centre. Therefore, whichever blade of the two stands south of east or west, toward the equatorial flow, is the magnet which governs the whole needle, and that which stands north of east or west presents less resistance to the flow, because the set of its molecules is with the flow and not against it, wherefore it is a mere negation; or, considering the needle as a whole, that end of it which points north may be considered the virtual north pole of the needle.

It should be observed, that in all cases where there are consecutive poles, (that is, contrary arrangements of the molecules), in the same blade, the directive energy of the equatorial flow appears very feeble, and the reason is plain, its effective force being measured by the difference between the combined lengths of the different arrangements.

In one instance, we succeeded in magnetizing so equally two blades, placed with their north poles together, and in a common centre, with their axes in the same line, that when placed at any small angle from east and west (magnetically) they would always polarize at right angles to the meridian. In this case the molecular angles set from the centre toward each end, and as the magnetized areas of each blade were equal, that is, as an equal number of molecules were raised on each side of the fulcrum, the equatorial flow could exert no more power over the one than over the other pole, and, as neither could turn north, it would consequently stand east and west. Yet, when this compass was laid at any large angle from the meridian, that end which was north of east or west would turn very feebly north. The reason was, the blade which was south of east or west then presented its angles to the south against the flow and formed a true polarizing magnet, whose north or governing pole was south of the pivot on which the whole instrument turned; while the blade north of the fulcrum or pivot, presenting its angles toward the north, afforded less resistance to the equatorial flow: thus, the whole needle was governed by the southern magnet.

The whole of these simple experiments are totally at variance with the hypothesis of two distinct magnetic fluids, under the pompous titles of the Austral and Boreal magnetisms. It is true, there is a calorific flow from the equator to the north, and another from the equator to the south, but their nature is identical, though their course is opposite. Yet the names may be retained for the sake of distinction and brevity.

If we be asked why other substances are not affected in the same manner, we reply, they are, in degree: for all substances have a tendency to polarize between magnets, that is, they are all subject in degree to the effects of the equatorial flow, as before shown; and as their textures, as well as their molecular arrangements, differ from those of steel, so also may the consequences be expected to vary. We may remark here, that sulphur, phosphorus, and other bodies, to which very great specific caloric is attributed, may in reality, owe this to the gases contained in the interstices of their molecules, and which form no part of the material itself, and the absolute calorific volume of these gases changing as freely as that of the atmosphere, on account of the porous nature of the body, the equatorial flow does not meet the same relative resistance as in the more compact bodies of the metals, and consequently, does not show its mechanical effects. It is, in truth, no more singular that all substances should not be similarly affected by magnetic caloric, than that they should not be similarly affected when subjected to the action of nitric acid or any other agent. That they are not is certain; *why* is another question, which we think we have already solved, by the relation which their specific heats and specific gravities bear to the general terrestrial flows of caloric.

What has rendered the subject of terrestrial magnetism more intricate than perhaps any thing else, is that one end of the needle is affected in the northern hemisphere while the opposite is unaffected; and yet, in the southern hemisphere, the end which was unaffected, is the very end subject to the magnetic influence, and the other becomes unaffected. We shall endeavor to account for this singular phenomenon.

In the course of solving the nature of magnetic polarity, we showed that it consisted in a certain arrangement of the molecular angles of the surface, (their disposition being from the leading pole or end of the magnet toward the other): we also showed that any magnet that was laid with its north pole toward the south would in time become weak in its powers, and, at last, have its poles reversed by the continual action of the equatorial flow upon its surface, causing the arrangement of the molecular angles to be reversed. Now, if this latter effect takes place in these northern regions where the magnetic power is, as we have proved in Theorem 6, Part I, so much weaker than at the equator, it is fair to suppose that the same effect would take place there much sooner; and this is rendered more probable from this fact, that a bar of soft iron placed in the direction of the dip, even in these latitudes, acquires magnetic polarity instanter, as proved by its effects on the compass. Now, if the effect is instantaneous in the case of soft iron in these latitudes, it is by no means singular that hard steel should be similarly affected, at the magnetic equator, for the compass is there in the direction of both the northerly and southerly equatorial flows; and, although the steel is harder, yet the flow is proportionally more active there also.

Proceeding south, when *over* the magnetic equator, the end which pointed north in the middle latitudes still continues to point north, because the needle is held in suspense by the two divergent northerly and southerly flows of caloric. Here, also, the intensity of the southern horizontal current reverses the molecular arrangement of the southern half of the compass, raising their northern angles, and pointing them from the south pole toward the fulcrum. Bringing afterwards the southern half of the northern end of the needle south of the magnetic equator, this portion of the needle will be similarly affected. Thus, three-fourths of the needle from the southern end have the molecular angles turned from that end toward the north, forming a directive agency toward the south, while only one-fourth has its angles turned from the north toward the south; so that three times the magnetic (or calorific directive) influence being exerted on the southern part of the needle, prevents the north pole (or former leading end) from veering round to the south, and becoming the leading end, or south pole, in the southern hemisphere, as it appears reasonable to suppose would be the case if the external molecular arrangement of the whole blade remained the same. It is, in fact, a compound magnet, consisting of two magnets whose axes are in one line, and as each is in its respective flow of caloric, they can have no disposition to swing round. When the needle has entirely passed south of the magnetic equator, the other fourth of it suffers in like manner, and the whole is then subject to the southern magnetic flow, or Austral magnetism: with the same ends pointing north and south that pointed so in the northern hemisphere. The same effect also takes place on the dipping needle.

Thus it appears, that the molecular structure of the surface, that is, the polar ends of the needle, is reversed on crossing the magnetic equator, and not that southern magnetism has a preference for one end of a needle, while northern magnetism has a preference for the other. We have very little hesitation in affirming, as a prognostication, that were a small pocket compass to be placed over a ship's compass, so that as a necessary consequence its north pole would look south, and the two compasses thus situated to cross the magnetic equator, it would be found, on releasing the smaller compass from the influence of the larger, that its former north pole would continue to point south, and its former south pole north; in other words, the poles of the compass would be unchanged, and the needle would in effect have veered round.

For, as in the northern hemisphere the molecular angles set from the north pole of the needle to the south, and as the action of the larger magnet causes it to veer round, that is, causes the molecular angles to set from the south toward the north, (why, will be shown hereafter), and as on moving south of the equator, it is already in a position to be legitimately affected by the southern equatorial flow, no change takes place in its molecular arrangement, and consequently, the north end points south, and the poles are not reversed. Notwithstanding, had a casual fact proved this before the theory suggested it, the general judgment would have erroneously pronounced that the poles were reversed, because it veered round, as it has already, that the poles of the mariner's compass do not change, because it does not veer round.

In fact, it is folly to suppose such a thing as a distinct magnetic fluid exerting a distinct influence in the southern hemisphere, and another in the northern hemisphere, and yet, that there is, as it were, a charmed line near the equator which this subtle fluid may not pass, although the grosser atmosphere, which it pervades, has free and uncontrolled licence of both hemispheres. If we are asked *how* caloric performs this miracle in the manner we have described, we shall reply socratically, How does caloric, in the form of electricity, hurl down the steeple from its towering height, or rend the solid oak? We only know that it does so; none will presume to question it. Why, then, should any one who admits such potency as this, deny its power over the compass needle? Thus much is certain, that nature performs her works in the most silent manner, under ordinary circumstances, and her most powerful ministers are apparently the most weak.

Is not the mere fact, that the *north* pole of the needle points south after passing certain *northern* latitudes, the finest proof that there is no such thing as a northern magnetic fluid of a distinct nature from the southern? Otherwise it is plain, from the above circumstance, that there are *four* magnetic influences, two in each hemisphere; one contained between the magnetic equator and the circle of magnetic confluence, and the other in the zone of neo-magnetic intensity.

By analogous reasoning, we think the needle, on crossing the centre of neo-magnetic intensity, might have its poles reversed; but as the flow there is very feeble compared with that of the magnetic equator, it might be unaffected.

The same principles are illustrated in magnetizing a needle by electricity. If we discharge the Leyden phial upon one end of the needle, allowing the electric fluid to escape by the other, the receiving end becomes the south, and that which gave off, the north pole of that needle. The reason is, the receiving angles being raised as the fluid passed over the molecules to the end from which it was given off, and as the resistance to the equatorial flow is toward the end which gave off, this end takes the direction of the general flow, and is the north pole of the magnet. But this holds good only in the northern hemisphere; for in the southern hemisphere, the calorific or magnetic current taking an opposite direction, the end which gives off, obeying the flow, turns south, and thus becomes a south pole.

Lightning rods are a further exemplification of this action. They become polarizing magnets, their upper ends being the south pole and their lower the north pole; for the upper ends receive, and the lower ends discharge the fluid, and the consequences are the same as in the case of electricity.

Also, it is probable, if a needle of steel, pointed at both ends, were to be applied by one end to the prime conductor of an electrical machine, and allowed to discharge the fluid silently, it would become magnetic, being similarly circumstanced as a lightning rod, the receiving end being its south, and the discharging end its north pole. If now we bring the needle, keeping it at right angles, gradually over the upper surface of the conductor, (which in this experiment at the point of contact is analogous to the magnetic equator of the earth), it is plain, when the receiving end has left the conductor, both ends discharge the fluid, which is supplied at some intermediate point in contact with the conductor. This causes each end to become a north pole, that is, the molecular angles set from them toward the receiving point or point of contact; which is consequently the south pole to each north pole, and the blade is a compound magnet, with a common axis. Now if the receiving end be moved one-fourth the length of the blade from the point of contact, the former north pole will be the governing pole of the blade, because this magnet is the larger one of the two; when, however, the receiving end has passed three-fourths the length of the blade from the point of contact, it becomes the governing pole for the same reason; and, when the former discharging end, or north pole, has come in contact with the conductor, being now the receiving end, all the molecular angles are turned toward it, and it is consequently the south pole of the whole blade. The poles of the blade are now reversed.

Thus the needle on passing over the magnetic equator or over an electrical conductor, is affected in a similar manner, having its poles reversed in either case. We hope this will satisfactorily account for one end of the needle being affected in the northern hemisphere, and the opposite in the southern. If it be so, it establishes the materiality of caloric, and its identity with the electric and magnetic fluids, beyond all doubt.

From the most attentive consideration we have been able to bestow upon this intricate subject, we have arrived at the following conclusion, viz: that *in a true magnetic needle there is but one pole or leading end*, formed by the uniform disposition of the molecular angles of the superfices, from that pole or end toward the other, which change their disposition, as the needle changes its terrestrial position, north or south of the magnetic equator.

We ground our belief upon these, among other circumstances: If part of the north end of a magnetized needle be broken off, the fractured end of this piece will become, *ipso* *facto*, a south pole; and if it be balanced on a pivot, it will be found that the north pole of the whole needle will be the north pole of the piece; if also the remainder of the needle be rebalanced, it will be found that the fractured end, (which was in contact with the fractured end of the smaller piece), is a true north pole; and if part of the south end of a needle be broken off, the fractured end will become a north pole: all which follows as a matter of course, if we admit that magnetic directive influence or polarity, is occasioned by the regular set of the molecular angles from the end of the needle that points to the destination of the calorific current, toward the point from which the directing current comes. It is evident on this arrangement, if the needle were snapped into fifty pieces, each piece must have a north or leading pole, and a south or negative pole, proving that the magnetic effect of polarity is only with relation to a stationary centre, and the angular set of the superficial molecules with respect to that centre. Also, if a magnetized wire, which on being balanced turns north and south, be bent round and joined at its two ends, the directive force of magnetism has no effect upon it; for there is no centre of preponderance with relation to the would-be poles and the set of the molecular angles, for the centre of equilibrium is not in the wire itself, but at a point which the wire encloses, proving that in this case it has no poles at all. Also, if a steel ring, magnetized all one way, (which has no polarity, as in the former case), be broken into twenty pieces, each piece will polarize; proving only, that each piece has a centre of preponderance with relation to the magnetic effect upon its two ends.

Yet we have been obliged to use the terms, "north and south pole," or we should not have been understood; and as they are conventional terms for the two ends of a magnetic needle, it is well to retain them. We consider the south end of the needle in the northern hemisphere a mere negation or cypher, and contrarywise the north end a mere negation in the southern hemisphere: we also consider that the north pole of the needle in the northern hemisphere would (as before stated) be the south pole in the southern hemisphere, if the needle could be introduced into that hemisphere with its north pole pointing south. The truth of this reasoning can easily be verified by any captain of a vessel, who would fix a small pocket compass by wax on the glass of a tell-tale compass, or ship's compass, pivot under pivot, so that the smaller one should point with its north pole to the south on crossing the magnetic equator; it would be found, on releasing it from the influence of the ship's compass, after having passed the magnetic equator, that it would continue to point south; that is, its pole or directing end would be unchanged, as on crossing the magnetic equator the poles of the large governing magnet are changed, the probability is the smaller compass would instantly veer round on passing into the southern magnetic hemisphere, or polarize east and west when on the magnetic equator. This would be a pretty method to determine the position of the magnetic equator.

The phenomena of magnetic attraction and repulsion have always been considered inexplicable. Why should a north pole repel a north pole, and attract a south pole, is a question which has been often asked, but never yet answered; unless indeed that hypothesis be considered an answer which supposes there are two magnetic fluids, that each repels its own particles and attracts those of the other: but this is entirely hypothetical, and ingeniously explains attraction by attraction, and repulsion by repulsion; which amounts to no explanation at all. It is, however, no wonder that these phenomena have been considered inexplicable, as the agent by which they are accomplished was unknown. We nevertheless conceive that *they may be resolved into the same principles as those of magnetic directive influence or polarity.*

As it is a physical fact that there is a current of caloric in perpetual flow from the magnetic equator to the coldest points of the arctic regions, (or the magnetic poles), and as we have shown that its direction is coincident, and its various changes of direction synchronous with those of the magnetic needle; it is now incumbent on us to show that this is amply sufficient to account for the change of direction experienced by two needles on approximating each other, and that it is also sufficient to account for the property which magnets possess of raising weights of iron. First, then, of the mutual influence exercised by two needles upon each other.—The whole is resolvable by the simple rules of the composition of forces. In order to render the subject more intelligible, we shall in the first place show that the influence of one needle upon another may be imitated without a magnet by the mere action of a current of water upon a surface furnished with angles, set in the manner we have ascribed to the molecular angles of a magnet as producing its polarity.

If we take a vane of any metal, whose superficial area and weight on each side of the pivot are equal, and whose whole surface is furnished with angles standing the same way, from one end toward the other, (similar, for instance, to the surface of a file), and put it into a current of water, it will polarize, that is, turn in the direction of the current; the end from which the angles set, looking toward the point of its destination. This end, therefore, is analogous to the north pole of the compass in the northern hemisphere, (and to the south pole in the southern). We shall denominate this the north pole of the vane, (as we are in the northern hemisphere), and its opposite, looking to the point from whence the stream comes, the south pole or negative end. The reason of this is, that the water, flowing into the angles, constitutes a force retaining the vane in its own direction. Turn it away, and it will return again. Cut off the southern half, and the northern half will still point as before, showing that its direction governs the whole: cut off the northern half, and the northern end of the southern half will still precede in pointing to the same direction, proving that the other parts bear the same relation to it now, that itself bore to the truncated part: and this is true, if the molecular set determine its direction.

As the whole volume of the current does not pass through the vane, and as it meets a resistance on impinging against the angles, it (the current) is deflected against the general course of the stream in the neighborhood of the vane, and forms local currents, retrograde to the general direction of the stream, as at Fig. 8.

This counter-current is, however, strongest at its source, and gradually lessens in power as it advances in opposition to the general flow, until at last it unites with it. At the same time, the body of water which should progressively occupy the place of the vane, is forced laterally from it, and causes a diversion of the general current. The course of the current, as determined by the composition of these two diverting powers upon it in the neighborhood of the vane, is, perhaps, a parabolic or hyperbolic curve; and affects the direction of the general flow to a considerable distance from the vane. The power of this counter-current is greatest near the vane, or place of its origin; and it is worthy of remark, that the larger the vane the greater the distance to which it will be perceptible, because a greater body of water is displaced from its course on approaching it.

The approach of another vane will disturb the position of the former. To comprehend this, we must study first the effects produced upon the general flow by the surfaces of the two ends of the vane. At the *north* end when polarizing, (looking to the destination of the current), there will be what we may call a *dead-water*, as at *a* Fig. 9, 10; not absolutely, but relatively, owing to its being partially protected from the action of the current, and as the fluid is gradually drawn out, there is a rush in from the sides of the dead water. A horizontal section of the true dead water would be triangular, the end of the vane being its base: this is produced by any obstacle to a current. This form, however, can only belong to the dead water of a body which presents no lateral obstructions to divert the current: when, however, there are lateral obstructions, as in the vane under consideration, the refluent currents divert the general current laterally, causing it to diverge from the body, and as it gradually loses its power, to converge again toward a point in the axis of the vane produced, its horizontal section, assuming the form of a flame, or of a fish with its head to the stream, and the point of convergence being near or far from the pole, or end of the vane, according to the momentum of the current, and the breadth of the obstacle. The *south* end has what may be called, in opposition to the effect of the current upon the north end, a *quick-water*, for the stream impinges upon that end, rebounds back, and is deflected laterally with the general flow.

Now, when two vanes, one large and the other small, are subjected separately to the action of the current, each turns its north pole, or leading end, toward the point of its destination; but when brought into each other's neighborhood, their counter-currents, (or local diversions of the general current), reciprocally affect each other. In this case, the general direction of the current is affected by *two dead-waters*, and *two quick-waters*.

Fig. 11.—Upon bringing the north pole, or *dead-water* of the smaller vane, to the south pole, or *quick-water* of the larger, so that their axes may lie in the same line, that is, in the direction of the general flow, they will not influence each other; because their counter-currents do not fall on each other. The contact of their north and south poles, in a continuous line, is equivalent only to an increase of the size of the vane, and cannot affect the direction of either, because the angles of each set the same way. There is then but one dead-water, and one quick water to the two.

Move the smaller vane south of the larger, (that is, toward the point from whence the stream comes), and with its axis still in the line of that of the other, and it will point true in the direction of the stream; for the same reason as when they are in contact.

Fig. 12.—Bring the north pole of the smaller vane near the south pole of the larger; move its pivot east or west, in the horizontal plane of its axis, and it will be found that its north pole will incline west or east, toward the south pole of the other; the larger one will also move simultaneously toward it, and they will be in the same situation as in the former case, viz: with their axes in one and the same straight line, if they are of equal powers, (i. e. diverting surfaces), and not too distant from each other; yet they will not look to the point of destination, but will note a variation from the direction of the current. The reason of this is evident. By reason of two neighboring obstacles, each of which causes local diversions of the general current, a vast number of eddies are formed by their resolution. Now, this retards the velocity of the current, and were the obstacle fixed, there is no remedy; but as in the case supposed, the obstacles are but partially fixed, and allowed to play on a pivot, the currents resolve their forces upon the vanes, and the stream is diverted less from its course when the axes of the two vanes are in the same straight line, than when they lie in parallel lines.

The same effects will evidently ensue if we bring the north pole of the larger vane to the south pole of the smaller.

If the small vane be allowed to polarize, that is, to look to the point of destination, as at *a x* Fig. 13, and the north pole of a larger vane, *c*, be brought obliquely S. E. or S. W. toward its north pole, in either the horizontal, vertical or oblique plane of its axis, the smaller one will move from the larger one on its pivot: if it be placed east, it will move west; if west, east; if above, downward or dipping; if below, upward. The reason is obvious. The larger vane, *c*, being placed S. E. (or S. W.) that is, obliquely to the general current, a larger body of water is displaced in its passage than when it looks in the direction of the stream;

in the first case the volume displaced is determined by the breadth of the vane, and in the second by the sine of the angle which its axis forms with the line of the current, and this diverted body, passing east and west, will form local currents to the east and west, diverting the smaller vane *a x* accordingly on its pivot, and oblige it to take the direction *b x;* and this action is also assisted by the molecular angles of the smaller vane producing counter currents resolving themselves upon those of the larger one.

The same reasoning will show that the south pole of one vane will repel the south pole of another.

Suspend the smaller vane under or over the larger one, so that its pivot may be in or near the vertical plane, passing through the axis of the larger vane, and it (the smaller) will turn round, its leading end or north pole pointing south, and its south pole looking north, or to the point of destination of the general current. The reason is obvious. The refluent currents from the larger vane, at their origin, are as powerful as the general current, and, as the smaller vane plays in a plane parallel to that of the larger, where the general current is counteracted and reflected back, it obeys this local current and takes its direction, that is, points with its north end south, or to the point from whence the general stream comes, but with its leading end or pole toward the destination of the local current. In all these cases the same stream is the cause of the contrary poles, (that is, of a leading and negative end), approaching each other, owing to their mutual action producing counter currents.

In our figures, we have pretended to give but a very general idea of the direction of the local currents in a fluid. The subject, however, is a curious one, and would no doubt solve magnetic phenomena clearly, if understood.

We may remark here, that if we break off a portion of the northern half of the vane, and balance it on a pivot, it will turn north, when subject to the current, and the fractured end will exhibit all the phenomena of a south pole:

and if we take a central portion of either the northern or southern half and balance it, it will still turn north, (or toward the point of destination of the stream), in the same relative position it occupied as when it formed a whole with the rest of the vane: also, that these portions will exhibit the same phenomena as the whole vanes they were taken from.

The same phenomena are exhibited on the approximation of two magnetic needles, as also by the approximation of their parts.

Now we consider caloric as material, and we have shown that it moves as a general stream; we have shown that magnetic steel is subject to its influence, and that that influence is external; therefore, the calorific flow is diverted in the neighborhood of a magnetic body, affecting locally the direction of the general flow, and consequently, affecting the direction of another magnetic body near it. We therefore think, that the general terrestrial flow of caloric, taking into account the diversions which it encounters from local obstacles, is sufficient to account for the polarity and dip of a magnetized needle, and for the influence which magnetized bodies mutually exercise upon each other; and particularly for those apparently inexplicable phenomena, the attraction of dissimilar, and the repulsion of similar poles. In short, we have no hesitation in affirming that all magnetic attractions and repulsions may be exhibited in a current of water: even those of the horse-shoe magnet, with relation to a compass in its vicinity.

As caloric, in its passage through a body toward the north, may suffer a refraction on entering the atmosphere a second time, it is not impossible that careful investigation may detect a difference in the dip of the same needle when situated north or south of any given body, the quantity varying with the nature of the material; unless, indeed, like refracted light, it takes the same course on emerging again into the atmosphere, as before it entered the interposing body.

But it may be asked, what is the reason that a magnet will raise a weight of iron? We answer, that the same force which moves one needle to another, will hold the bodies in contact with each other, by the exclusion of the current from the point or surface of contact, and that the force necessary to sunder them is in some proportion to the momentum of the current, and the areas of the surfaces in contact.

If we bring two smooth surfaces in contact under water by the intervention of a little oil, so as to exclude the current of water from between them, it will require some considerable exertion to separate them, by an effort vertical to the plane of contact; but if we endeavor to separate them by slipping their surfaces over each other, we shall easily accomplish our purpose. The greater the areas the greater the exertion requisite by the first named means; but it hardly affects the second. Now the same is the case with the magnet and the attracted substance.

If we bring any small body within a short distance of the *quick-water* or *dead-water* of the vane in a common current of water, it is manifest that it will remain there, or be attracted, as the expression is; but it is equally manifest that the quick-water, or south pole of the vane, will support a larger body than the dead-water or north pole. Now, this is precisely the case with a magnet; in this hemisphere, the south pole supports a greater weight of iron than the north pole; and doubtless the reverse (as the poles are named) in the southern hemisphere. It is also manifest, that the more impermeable the substance attracted is to the current, the greater will be the force with which it is retained at the polar end of the vane. This, also, is the case with the magnet; for we have before shown that iron is more impermeable to the calorific flow, than the other metals, with the exception of cobalt, and this substance is magnetic, that is, attracted by a magnet: we have also shown, that nickel is more impermeable than the other metals, and this metal, also, is magnetic. We have also shown, that soft steel is more impermeable than iron; wherefore, a magnet will raise more soft steel than iron; and, as hard steel is yet more impermeable than soft steel, it explains why a magnet will carry more hard than soft steel. And, as we have shown, in treating of the variation of the dip and direction of the needle, that the power of the magnetic flow varies between summer and winter, midday and midnight, there will, of course, be corresponding periodic variations in the sustaining power of magnets.

The reason why iron is attracted, in preference to other substances generally, and by either pole of the magnet, we conceive to be owing to its molecules being arranged in no particular order, that is, having no poles. But, if a bar of soft iron, which, when laid east and west, attracts either pole of the magnet, be held perpendicular or near the direction of the dip, its lower end will immediately become a north pole, and repel the north pole of the compass, while its upper end will become a south pole, and repel the south pole of the compass. The reason is this: The bar, by the slightness of its molecular cohesion, has its molecules instantly arranged by the general calorific flow, and is a polarizing bar, and consequently affects the magnet; but, as they are merely retained there by the flow, they return instantly to their natural position on being removed from the action of the flow.

A convincing proof of the truth of the powerful effect of an augmentation of specific heat, in opposing the passage of the equatorial flow, is exhibited by the late experiments on galvanizing a horse-shoe magnet, in which the current of galvanism passes into the magnet, and increases its power in an almost unlimited degree; this causes a greater resistance to the equatorial flow, and, consequently, increases its external action on it. By the same means soft iron becomes highly magnetic, and these effects are not confined to iron alone; for powerful temporary magnets may thus be made of any metal.

There is a particular phenomenon which confirms our view of the nature of magnetic attractions and repulsions. If we bring the north pole of a small needle toward the north pole of a larger, (or *vice versa,* the south pole toward the south pole), they will repel each other; but if brought within a very small distance, they will attract each other; and there is a boundary line between the regions of attraction and repulsion, which may be denominated a neutral ground, for there neither attraction nor repulsion take place, each remaining stationary. This seems capable of an easy and simple explanation. The repulsion has been explained when we showed the nature of the repulsion of similar poles. The attraction, within a certain small distance, may be explained on the principle of capillary attraction, whatever its cause. The neutral ground is the result of the balance of the two forces, or the boundary of their dominions.

We sincerely hope we have thus satisfactorily explained the nature of magnetic attractions and repulsions, on known and acknowledged principles.

In considering the instruments which derive their utility from their physical or adventitious properties, with respect to magnetic caloric, we shall make a few remarks on their construction, and the manner in which the magnetic effect should be communicated.

The vertical or dipping needle is acknowledged to be a very imperfect instrument in its present state, as the indication by one observation can never be relied on; and therefore, the usual method is to reverse it on its gudgeons, and take a mean of the two results. Now, it is evident this must also be incorrect, as it is either a mean between a right and a wrong result, or between two incorrect results. And further, no two needles give the same indications.

This imperfection we consider as owing to the manner in which polarity is communicated to the blade. The usual method is, by passing the contrary poles of two magnets separately or simultaneously from the centre to the ends of the bar, or by passing one pole of a magnet from end to end. Now, from the solution of the cause of polarity, which we have given, as produced by the arrangement of the angles of the superficial molecules, it is evidently impossible to polarize the blade truly in this way. For the mere variation of pressure, an irregularity of surface, and a thousand other unforeseen circumstances, will cause an irregular set of the molecular angles in various parts; that is, produce different poles in various parts. Accordingly, Mr. Pike, optician, of Broadway, New York, assured us, that having occasion once to magnetize a long needle, (two feet or more in length), he found it utterly impossible to effect his object without intervening poles; but having accidentally dropped it upon a nail or other piece of iron, on proving it, he found that it had instantly only two poles, a north and a south.

This is as it should be, upon the molecular explanation of polarity we have advanced, and the manner in which we have explained the spontaneous acquisition of this property by a bar falling endwise. For, if the magnetic effect be communicated by the discharge of electricity upon one end of the blade passing off at the other, by a fall which jars all the external molecules uniformly and simultaneously from end to end; or, by a blow on the upper end when held in the direction of the dip, producing the same effects as in the case of the fall; in all these cases the action is uniform from end to end, the superficial molecules are uniformly arranged, and two poles only are the consequence. So that the communication by the magnet is the worst means that can be adopted. Any other way is preferable to this.

Having shown that the magnetic action is external, it is evident we must look to the nature of the surface of the blade to solve the cause of the imperfection of the instrument. We shall here at once perceive, that the different extent of surfaces exposed to the magnetic action, as compared with the different degrees of friction on the gudgeons, the different lengths of the blades, and their different absolute and specific weights, must necessarily cause every needle, as at present constructed, (the momentum of the equatorial flow being equal to all at any given locality), to mark different angles under similar circumstances. When, also, the supporting sides are horizontal, their attraction on the blade decreases as the dip increases, because of increase of distance: and when they are perpendicular, the attraction increases as the dip increases, because of increasing proximity.

The following is the best plan we can suggest, in order to obtain the full magnetic effect, and avoid the ill effects of the proximity of the supporting sides, and of local attraction.

The blade or needle itself should have its substance so disposed as to present the greatest possible effective surface to the calorific current. To effect this, if the blade be flat and thin, it should be laid with its breadth in a horizontal and not in a vertical plane, as is usual at present: for, as the magnetic action is superficial from above downward, the vertical width only forms an hindrance to its fair play; as every increase of vertical thickness does not add to the magnetic effect in proportion to the increased inertia to be overcome. But the most perfect method that can be adopted to obtain the full power of the flow, is to dispose the matter of the blade in the form of a hollow cylinder, open at both ends: this allows of an internal, as well as external directive action of the flow. It is well known, that the more clumsy a needle is made, that is, thick in proportion to its length, the more sluggishly it traverses, and the reason is obvious: the surface, to which the magnetic action is confined, is not increased in proportion to the increase of matter; the inertia is therefore increased, while the power of the flow remains the same.

When the poles of the needle are reversed, it will be found that the two observations measure different angles. The reason of this is, (if they be equally magnetized or polarized), the superficial areas of the two halves of the blade vary; wherefore, also, the magnetic effect, being superficial, will also vary. The two ends should, therefore, be made to mark the same angles under the same circumstances, or, as it might be expressed, to *balance magnetically as well as physically*, without which the instrument is inaccurate.

The vertical thickness should, therefore, be as little as is consistent with the requisite rigidity of the instrument.

But still, any two instruments will vary, unless certain relative statutory dimensions, in proportion to length and gravity, be agreed on by mathematical instrument makers; because, otherwise, the respective inertiæ will vary, and consequently the magnetic effect. They will also vary, unless the magnetic, (or more properly the polarizing), virtue be communicated in some certain and determinate manner: such, for instance, as an electric discharge from a certain extent of coated surface, or a certain agreed intensity of galvanic action, or a fall from a certain height on to a certain given weight of iron or other metal, or a blow of a given intensity applied to the upper or under end when laid in the direction of the dip: and all this, when the barometer, thermometer, and hygrometer, give certain conventional indications. We may also add, that the blades should be formed and hardened at the same temperatures, under the same circumstances, by the same means, and of the same metal, as near as possible; for otherwise, the nature of the metal varies, that is, its atomic construction, its specific, and consequently its absolute caloric, and therefore, also, the magnetic effect. Perhaps, also, a similarity of magnetic latitude, particularly in conjunction with a fixed period of the year, thereby insuring an equality of magnetic intensity, might secure additional accuracy. All these things attended to, there would be no necessity to reverse the gudgeons, as at present, in taking an accurate observation.

The brass box in which a well-constructed needle usually plays, and which is placed in a vertical place, should have two *soft iron* wires, sunk into two grooves on the outside, between which the blade should track in its course. The proximity of the iron rings would prevent the effects of local attraction; and the sides of the box being closed with plate glass, should have an arm projecting from each plate toward the centre, for the gudgeons of the blade to play on. This would prevent the ill effects of the varying proximity of the supporting sides, as their proximity and effects are uniform. There should be a graduated scale on each side of the needle. When used to ascertain the magnetic intensity, it should be hung so as to oscillate in the horizontal plane of the dip; on the plan pursued by professor Hansteen.

The horizontal or compass needle should be furnished in order to prevent local attractions, in the excellent manner invented by professor Barlow, of Woolwich, in England.

Magnetism is the result of the grand terrestrial effort which nature makes, to equalize the difference of equatorial and polar temperature, and to carry on the general process of evaporation, which is proved by the polar course of the needle, in a dipping direction; modified, however, by disturbing causes, acting on a grand scale, as shown in discussing the nature of the variation. Local difference of temperature has no part in the production of the phenomenon; but it alters its intensity, as proved by the oscillations of the needle; the number of which varies in a given time, in the same place, at different seasons of the year, and different hours of the day. Yet the local difference of temperature which alters the relation of fluid and solid surfaces, on a great scale, as the descent and retention of vast bodies of ice on the polar sides of the continents, altering the position and intensity of the magnetic poles, or centres of the polar continents, or the freezing over of vast inland seas, will cause a general deviation of the body of caloric from its course; and consequently this affects the variation. The difference of meridianal temperature, causing the diurnal variation of the compass needle, may be considered a general cause, as it operates from pole to pole simultaneously.

It now becomes our duty, to anticipate some objections which might be raised against the theory. It may be asked, "If caloric be the cause of the polarity of the magnetic needle, why is it not sensibly affected on approaching a fire, or an iceberg?"—For we have experienced this objection, as if it were an established fact. We shall show it to be futile.

We shall state in the first place, that the objection is not a fact; for that the presence or absence of warmth does actually affect the needle. To establish this, we shall refer to the observations of the scientific gentlemen, who accompanied the late polar expeditions under captain Parry. It was found that though the needle would not traverse freely, on the deck of the vessel, when in winter quarters, it would traverse freely when taken into the cabin, heated by a stove. This, therefore, clearly shows that the presence or absence of caloric does affect the needle. In order also, to arrive at the reason why a needle is not very obviously affected by a stove or other reservoir of heat in our latitudes, we must bear in mind where the above observation was made: if we mistake not, it was in Winter Harbor, Melville Island.

Now, this being very near the magnetic pole, or centre of greatest cold, the general equatorial, (or, as this place is within the circle of magnetic confluence, the general neomagnetic), flow is necessarily very weak, compared with that at the equator, inasmuch as it has nearly arrived at the zero of the series expressing the force of horizontal magnetic intensity, and is consequently nearly exerted in a vertical direction; therefore, the flow from the heated stove adds a fresh volume and impetus to the general flow, and causes a local increase of magnetic intensity; and as its source is situated near the level of the pole, its momentum counteracting the general flow in a horizontal direction, causes this latter to approach nearer the horizon, and thus causes the needle to traverse better. We even think a diminution of the dip may be observed on the southern side of a stove, in these very high latitudes. We have shown, however, that the momentum of the horizontal flow is greater in the middle latitudes than near the pole; if, therefore, the momentum of the radiation from a stove, be merely sufficient to affect the needle's intensity near the pole, we must naturally conclude that the same amount of radiation will not sensibly affect it in the middle latitudes.

It is palpable, that if the horizontal needle be placed magnetically south of a stove, in the middle latitudes, it will not be affected in direction, but its intensity will be reduced; if north, its direction will be unaffected, but its intensity increased: in the first case, the equatorial flow is retarded, and in the latter accelerated, but the direction in either case remains the same. If, however, we bring the needle magnetically east or west, we must expect that the radiation will act in degree on the general equatorial flow, and cause a corresponding variation from the magnetic meridian or paropsis; but, for the reasons before assigned, it is very probable the amount will be imperceptible.

In the vicinity of an iceberg, in the middle or tropical latitudes of the northern hemisphere, the converse of the above phenomena will be exhibited, as it is a local centre of cold, affecting the general flow. Magnetically north and south, the direction will remain unaltered; but the intensity will be diminished to the north, and increased to the south; for the equatorial flow to the north of it will be retarded, and to the south of it accelerated in degree. Magnetically east and west, however, as there is a tendency to divert the equatorial flow toward the berg, there will be a corresponding variation from the magnetic meridian, or paropsis; but it is very probable the affection would be imperceptible.

The truth is, these causes act on too small a scale to affect the momentum of the local calorific currents materially.

There are other causes affecting the needle, which some admit, and others deny; such are storms, whether of snow, rain or hail; also winds, the aurora, and other meteoric phenomena. Now, as these are connected with the agency of caloric, and as they frequently act on a great scale, they must doubtless affect the needle. We may conclude they will not affect the horizontal needle, when very near, or over, or magnetically north or south of the spot of observation; because then, as in the above case, the passage of caloric, as affected by these causes, from or to the needle, as the case may be, is in the line of the magnetic meridian; but the dipping needle would probably be affected. Magnetically east and west of the spot of observation, it is highly probable the direction of the needle might be affected sensibly; and particularly south-east and south-west, north-east or north-west. Perhaps the angular transmission of caloric, from or to the spot of observation, occasioned by the condensation or solution of aqueous vapor, and other meteoric phenomena, in the upper regions, may cause the quivering which some have occasionally noticed.

In the late polar expeditions, (if we recollect right), the needle was generally supposed to be unaffected by the aurora. It will be observed, that the instrument was north of the magnetic pole, and that the phenomenon of the aurora was stated to happen most frequently to the southward of Melville Island, probably over the magnetic pole itself, in which case the needle would certainly be unaffected, as it would point toward the phenomenon.

It is nevertheless evident, that at latitudes and longitudes intermediate between the two northern magnetic poles, as at London and Paris, these affections would be more sensibly felt than at places nearer the meridian of the pole. And the observations of M. Arago, at Paris, tend to confirm this.

Thunder storms, extending over large surfaces, affect the direction of the needle when situated at a distance from the place of the storm, but not when situated under its influence; in this latter case, a quivering only would most probably ensue. A thunder storm cools the atmosphere by passing off the electricity; therefore, the atmospheric temperature of the neighbornig places is higher, and a flow ensues toward the region of the storm, which will affect the needle accordingly.

A remarkable proof of this affection occurred during the course of the magnetic observations instituted by Col. Beaufoy, at Hackney Wick, near London. The greatest variation in May, 1813, was on the 3d of that month. At 8 h. 5 m. A. M., the variation was only 24° 9′ 45″ west, and continued to increase to 2 h. 35 m. P. M., when it was 24° 26′ 20″ west, *during which time there was a great deal of thunder in the west.* Thus, the point of meridianal refrigeration being to the west, caused a large increase of the ordinary diurnal variation to the west. *The next day, when there was thunder in the east,* the greatest westerly variation amounted to only 24° 16′ 30″, being a diminution of 9′ 50″ in the variation as compared with the previous day. Here, the point of meridianal refrigeration being to the east, caused a diminution of the ordinary diurnal variation.

Another curious affection of the needle, produced by lightning, was related to us by captain Martin, of the ship Atticus. Being off the Bermudas, he encountered a tremendous storm; it lightened all round, in rapid succession, and for the space of an hour or more the needle was useless, moving round and round, indicating all points of the compass as frequently as three times a minute. It seemed as though the needle had lost its point of direction, and was moving round to find it.

As another connecting link in proof of the calorific theory, we may mention that a needle of any metal, delicately suspended by a single thread of silk, and heated at one end, is now admitted to exhibit magnetic phenomena. It is evident, that the actual augmentation of its absolute caloric causes a greater resistance to the passage of the equatorial flow, and when heated unequally by the application of a lamp at one end, the elements of polarity are gained, without consideration of the molecular arrangement of the superficies; for, if we suppose the blade placed at right angles to the magnetic meridian, the equatorial flow will find greater difficulty in changing the identity of the absolute caloric of the heated end, than of that of the opposite end, and consequently, the the former will precede the latter, in turning to the destination of the general flow.

From what has been advanced when treating on the magnetic divisions of the globe, the intimate connexion which must evidently exist between the climates of the northern countries, and the lines of variation, no variation, and dip, dependent on the situation of the points of greatest cold or magnetic poles, owing to the increase or decrease of ice in the northern sections of the continents, and to the disposition of land and water, renders the subject of climatology, as connected with magnetism, a very interesting matter of inquiry.

It is a pity we have no accurate accounts of the state of the continental climates in ancient times. For want of the indications of the thermometer and barometer, the only clue we can obtain to mark the different changes which have taken place, is the knowledge that such and such plants, &c. have thriven in such sections of the continents, in certain ages, and in others have become extinct; and that subsequent ages have seen them return to their wonted haunts. When we connect these facts with the now known motions of the cold poles, we may draw some very important conclusions on the nature of the changes to which the climates of the northern portions of the continents are liable.

If we look at the arctic regions of the western and eastern continents, we shall perceive a vast difference in the ability of shifting their respective poles. The former extends farther north than the latter; its land reaching at least to lat. 80°; and being included between the meridians of 10° and 170° west, or 160 degrees of longitude from Bhering's Straits to the east of old Greenland. It may extend farther north; but, from the position of its magnetic pole or point of greatest cold, midway between the arctic circle and the parallel of 80°, and in the centre of its longitudinal spread, its seemingly natural position, we do not think it extends more than a few degrees farther, say to 83° or 84° N. The eastern continent, on the contrary, extends only to 72° N., with a few points of land extending beyond, and is contained between the meridians of 20° E. and 170° W.; being 170 degrees in longitudinal extent.

Arctic America, therefore, cannot materially alter its continental surface by accumulation of ice to any extent; because it presents no resting place for it, unless it be north of 83° or 84°, when the degrees of longitude grow very contracted. In this case, the only effect would be to carry the pole farther north, without materially affecting its longitude. Accordingly, we find the American pole has been nearly stationary, having only shifted so as to cause a difference of variation of about 4° at Boston in about 170 years. The variation at that city being only about 11° W. at the time when the European virtual line of no variation passed over London, in 1657, and at present about 7° W. The accumulation of ice on the west of the northern coast seems what would affect it most.

The range of the northern coast of the eastern continent being confined to 72° N. latitude, presents a vast obstacle throughout its whole extent to the descent of the polar ice into the southern seas. For if we assume, for sake of whole numbers, that a degree of longitude in the latitude of 72° be 21 miles; then is the surface it presents 3600 miles in extent; whereas, the same number of longitudinal degrees bounding the western continent in latitude 84° north, presents only an extent of 1200 miles.

The hitherto impassable Cape Taymour, stretching its rugged coasts as far north as lat. 78°, exercises a particular influence, it will be readily perceived, on the descent of the northern ice; dividing it into two main bodies, the eastern and the western. The latter finds no difficulty in escaping into the North Atlantic, through an opening 40 degrees wide, in latitude 70°; and thus annually leaves the northern coasts of Europe nearly free of ice. But not so with that body east of Cape Taymour; owing to the narrow exit afforded by Bhering's Straits, but little can escape that way; and therefore, the far greater portion to the east of this cape must chiefly remain there till late in the season, when it may find a passage into the Greenland seas, by the set of easterly currents, and from thence south, when the western body has made its escape. So that this part of the coast must always present an impassable barrier to vessels, unless by proceeding east after reaching lat. 80° or 82°, in order to keep clear of the drift ice on the northern coasts.

There is reason to believe the seas north of Asia, from latitude 82°, are always open, and it is certain that the mean temperature is there higher than farther south. To establish this, we need only mention certain known facts. The fishermen, from the north of Europe, on proceeding about seventy miles from the coasts, in pursuit of the morse and seal, in the month of March, perhaps as keen a month as any in the year, are in the habit of throwing off their winter clothing; but on returning, about the middle of May, they are obliged to resume it, when within twenty or twenty-five miles of land. Also, it is an established fact, upon the experience of the inhabitants of the north of Europe, that a north wind, continuing twenty-four hours, invariably brings on a thaw, and is the mildest wind they have in the dead of winter. To all this we may add, that though the rein-deer loves a cold and dreary country, yet, on the approach of winter, they leave the regions around the magnetic pole of America, and migrate to the north, from whence they return in the spring, fat and well-liking. We may also add, that on the late polar expeditions, the north wind at Winter Harbor, in Melville Island, was unquestionably milder than one from the south. Upon the whole, then, we think the north-east passage is practicable to vessels proceeding boldly north, before they bend their course to the eastward.

But this is deviating from the subject. To return then: Upon looking at the extensive range of the northern coasts of Europe and Asia, (as compared with those of America), we perceive at once that the increase of continental surface may be accomplished to any extent when the ice breaks up in a quiet season, and altering the centre of the arctic continent, the intensity of the cold will be increased proportionally with the increase of surface; let but the ice block up the Greenland seas, and encroach upon the range of coast, between Capes North and East, as far north as lat. 83°, and the intensity of cold in Arctic Asia may be equalized with that of Arctic America. In this case, supposing the Asiatic pole or point of greatest cold to be situated about the longitude of 95° east, latitude 70° north, and the American about lon. 105° W., lat. 70° N., the European virtual line of no variation, (being the line of the balance of their power), at present situated near the meridian of 45° E., would move westerly to that of the island of Ferro, whose meridian, 18° E., is intermediate between the two poles. Europe would then be exposed to the rigors of a climate but little inferior to that of the eastern coasts of North America.

This was actually the case once. Before the year 1492, when this country was discovered, the variation of the compass was unknown, and the reason was simply this. The meridian of Ferro passes nearly along the western coasts of maritime Europe, and therefore the variation could be but small, and consequently unobserved in those parts; add to which, the compass was then used chiefly in navigation, and the only general phenomena known concerning it were, that it pointed north and south, the temporary affections it was liable to being unknown. Now, in the year 1406, the court of Denmark sent out the 17th bishop to her colonies of East Greenland, before that time a fine and flourishing colony, having been settled upwards of 500 years, and called Groenland or Greenland, from its beautiful appearance; a word of Scandinavian or Icelandic origin. The vessel in which he embarked proceeded as far as Iceland, and could approach no nearer to her destination, on account of the ice. The colony has perished; thousands of human beings have died a dreary death, and innumerable flocks and herds have perished with them; not a soul has escaped from this land of desolation to tell the horrid tale of how a nation may be swept from the face of earth; and though the Danish government made many attempts to relieve the sufferers, what could human means do to surmount the barrier of a winter that was to endure 400 years? In later times, Paul Eugede has crossed the peninsular from the western colony, and the ruins of their towns, their churches, and monasteries, alone mark the spot where once a considerable trade was carried on with Europe. There is one interesting fact connected with this long-forgotten colony, that deserves attention; viz: that it is very probable the island of Newfoundland was discovered by one of its sons, and called by him Winland, and perhaps, also, the coast of Labrador. From that year, (1406), to the present time, the eastern coast of this inhospitable land has been inaccessible; but it is the opinion of captain Sooresby, to whom much deference is due, that some of the more southern parts are now accessible, perhaps, during the height of summer. Simultaneous with this event, the climate of Europe underwent a most material change; late springs, early autumns, and long and severe winters ensued; but for many years past the climate has ameliorated much.

As the climate of Europe has been progressively ameliorating, it is worthy of remark, that the virtual line of no variation, or balance of power of the two northern poles, has retreated easterly; showing clearly, that the Asiatic pole has decreased in intensity, (as before proved), causing a smaller demand of the existing volume of caloric in the west of Europe to pass to the east, in order to equalize its atmospheric temperature with that of polar Asia; thus affording a good and sufficient reason for the mean increase of annual temperature in the west of Europe. In fact, this is a necessary consequence, for as the same quantity of caloric may be presumed to be delivered annually by the sun, the climates of the northern countries depend on the direction in which it is distributed from the tropics.

If this theory be correct, if caloric be the cause of the polarity and dip of the magnetic needle, (and there can be no reasonable doubt of it), the motions of this virtual line of no variation, or what is the same thing, the virtual lines of variation resulting from it, will be watched in Europe with Argus eyes, by future philosophers, who will from hence be able to prognosticate an approaching change of climate, for better or for worse. As the virtual variation increases westerly by the easterly retreat of the virtual line of no variation, in consequence of a diminution of the intensity of the Asiatic pole, the inference is that the climate is improving; and should the virtual variation decrease constantly for any number of years, the contrary must be anticipated.

The climate of the old continent, (with the exception of Siberia), can never be so extremely cold as that of the new, in the same latitudes. For, in the western hemisphere, the surface of the land bears so small a proportion to that of the water, that a large part of the equatorial flow is expended in passing over the ocean, and combining with its waters in a latent state. Besides which, the disposition of the land is materially different in the two continents. In the western continent, (we refer only to the northern hemisphere), there is but little land within the tropics; the terrestrial surface, however, spreads, as it advances north. In consequence of this, a large part of the equatorial flow, in its progress toward the pole, is expended on oceanic evaporation, and never reaches the coasts in an active state; and to supply the deficiency in some measure, the equatorial flow over the continent spreads in advancing north, and thus diminishes its sensible effects; which also causes the temperature of its magnetic pole, or point of greatest cold, to be reduced very low. In the eastern continent, on the contrary, the southern sections are more extensive than the northern, and therefore the equatorial flow continues with greater activity to higher northern latitudes; for it is not so freely expended on evaporation, as the surface of moisture exposed to its action is but small.

It has been frequently asked, why the eastern coast of each continent is colder than the western, in the same latitudes, during the winter season? The question has been attempted to be solved by some, by the condensation and precipitation of vapor, which is well known to be more abundant on the western coasts of the old, than on the eastern of the new world; and which is also known to be accompanied by the extrication of the latent heat of vapor. But as the precipitation of atmospheric vapor is occasioned by a reduction of temperature, and as the eastern coast of the western continent is actually at times colder than the western of the new, the greatest amount of precipitation should take place on the former coast, and thus equalize its temperature with that of the latter. We shall therefore endeavor to account for the phenomenon otherwise.

The eastern coast of each continent trends south-westerly about 25° from the parallel of 50° N. to the tropic; therefore, the general equatorial flow of caloric, proceeding from the magnetic equator nearly northerly, along the meridians which intersect the coast, loses its power in a great measure before it reaches the northern sections of the coasts, in the temperate zone, by combining rapidly in its transit, with the surface of the ocean, so freely exposed to it; whereas, had its course been over land, it would have continued active for a much greater distance to the north, in consequence of the reduced quantity of moisture exposed to it in that case. The western coast of Europe, on the contrary, trending in the same direction, (south-westerly), about 20° from the parallel of 60° toward the tropic, meets the equatorial flow to the west of it: this causes the general flow to pass over the land, in its way to the north, diminishing, consequently, the expenditure in evaporation; and concentrating, (in comparison with the effects of the eastern coast), as the degrees of longitude contract, the flow retains its activity or sensible temperature, farther to the north. The scorching plains of Africa, also, raise its temperature materially, by supplying an unnatural equatorial flow, owing to the want of sufficient moisture throughout such an extensive track to pass it off in a latent state; and which would considerably increase the effect, were it not counteracted in a measure by the inland seas it passes over in its course toward Europe.

It may be objected, that the western coast of North America is exposed to the same cooling influence as its eastern coast, because it trends in a south-easterly direction toward the eastern coast, and that therefore it should be as cold as this latter, while the contrary is the fact. We reply, it would be so, were there not a counteracting influence.

The long and lofty range of the Rocky Mountains and Cordilleras, running parallel with the coast, prevent the caloric west of them from spreading to the east, and cause it to flow north-west over the land, thus retaining its activity farther north; and this very prevention of its spread is what occasions the greater mildness of the western coast as compared with that of the eastern in the same latitudes. Were it not for this coasting range of mountains, the north-western sections of the continent would be even more severe than the north-eastern, because the western coast trends 10°

more to the east in proceeding south to the tropic, than the eastern coast does to the west.

Yet, though the west coast of North America is warmer than the eastern, it is not so mild as the western coast of Europe in the same latitudes: for it has not an Africa to the south of it, nor an open sea to the north of it: besides which, the equatorial flow toward it passes for 30° of latitude over the ocean, before it reaches the continent.

The extremes of climate are felt much more sensibly at New York than at London. This has been generally attributed to the marine climate which England enjoys: yet as New York is situated on the seaboard, and 12° further south, this cannot be considered the only cause: the solution of the phenomenon must therefore be sought in other sources.

When the sun is on the northern tropic, it is 12° nearer to New York than to London, being about 16° 30′ from the zenith of the former, and 28° 30′ from the zenith of the latter city: so that it is no wonder the temperature should be higher at the former than at the latter city in the summer season. For the sun is then nearer the zenith of New York, and further from that of London, than it is from that of any place on the equator; taking, therefore, the temperature of the equator as the standard of comparison, the former ought to have a temperature above, and the latter a temperature below that of the equator; i. e. that New York should exceed London in temperature at the summer solstice. The truth is, the proximity of the sun to New York, at that season, more than counterbalances the cooling of the northerly equatorial flow from the magnetic equator, when passing over the ocean, in its passage to the north-eastern sections of the continent.

When the sun is on the southern tropic, or about 63° 30′ from the zenith of New York, the magnetic or cold pole of America is at its most southerly declination, bringing that city more within its sphere of influence; but owing to the very westerly position of London from this (its present governing) pole, and the south westerly movement of the pole itself, this latter city is no more influenced by it in winter, (as respects its proximity), than in summer. So that London has this advantage over New York, that it is no nearer the cold pole in winter than in summer. Add to this, that the general equatorial flow, passing from the magnetic equator, is very sensibly diminished in effect before it reaches New York, as it passes over an immense extent of ocean, because the sun is then situated south of the magnetic equator: while London, on the contrary, receives its general equatorial flow from the still burning sands of Africa, which passes for the most part over land, thus retaining its activity farther north, on account of the diminished demand of marine evaporation.

With reference to the climate of the eastern and western coasts of South America and Africa, south of the magnetic equator, they are uninfluenced by the direction of the equatorial flow, because it is flowing from their widest to their narrowest ranges, as their coasts converge toward the southern magnetic pole. The greater range of temperature of the eastern coast of Africa above that of the western must be sought for, consequently, in other causes. Now as the magnetic equator, or line of greatest heat passes north-east to the eastern coast, and south-west to the western coast, across the terrestrial equator, in order to join those parts of it respectively north and south of the equator, it is reasonable to suppose that the parallels of equally diminishing mean temperature, or what is the same thing, of equally diminishing mean annual evaporation, will take the same general direction as the line of greatest heat, and thus occasion a higher temperature on the western than on the eastern coast, in the same latitudes. The same reasoning will also show that the eastern coast of South America should be of a higher temperature than the western. The set of the mountains, also, and the neighborhood of the ocean are favorable to a settled and mild climate to the west of the Andes.

The eastern and western coasts of New Holland, the fifth quarter of the world, as some geographers have named it, will be unaffected in their relative temperatures as respects the equatorial flow, as it comes to each over the ocean, unless indeed we look to the line of no variation, caused by a south-westerly and south-easterly divergence, dividing the island into two nearly equal halves; in which case, the flow being south-west over this continent toward the western coast, and south-east toward its eastern coast, the proximity of land toward the eastern coast will render this latter warmer than the former. This view is also borne out by the direction of the lines of equal dip passing through this island, which descend farther south on the eastern than on the western coast.

It is worthy of remark as affecting their climates, that the chief peninsulas of the world, with the exception of Labrador, look south: consequently, those north of the magnetic equator present their smallest width to the general flow, and those south of the magnetic equator their greatest. The peninsulas of the northern coasts of the arctic continents, of course, look north; but these are small, with the exception of Taymour.

In treating of the variation, we proved, from the actual state of the southern variation, that there was but one southern magnetic pole, and that it was situated somewhere about the meridian of 10° W., it may even be on 0° or 20°; we then stated our opinion that there was a large southern continent, whose point of greatest cold or magnetic centre, was the pole alluded to. Now it is well known, that the intensity of the cold in high southern latitudes is excessive, and that the ice extends farther toward the equator in the southern hemisphere than in the northern. Why is this? The answer is obvious. The southern continent, the existence of which we firmly believe, and of which we think Palmer's and Sandwich Land may be the northernmost points, or skirting islands, is entirely separated from the magnetic equator or line of greatest heat, by a vast ocean; and as the middle and tropical latitudes are occupied also by the waters of the oceans, the southerly equatorial flow is necessarily greatly reduced in volume by the demand occasioned by the very great evaporation of so extended an aqueous surface. This, then, is doubtless the reason of the excessive cold in high southern latitudes.

From the remarks we made, when looking at the forms of the arctic continents, it is manifest that the Asiatic pole is the cause of the variations of climate to which Europe is subject, and not that of America. The American pole is nearly stationary, by reason of the high latitudes to which that continent extends, and the form of the outline of its arctic regions, and consequently, also, nearly steady in intensity or power; while that of Asia, fickle and inconstant, may wander north and south, (and perhaps even east and west), in an extensive range, and alter most materially in intensity with the increase and decrease of its continental surface of ice. This will necessarily cause a much greater change in the positions of the lines of calorific or magnetic variation and no variation, belonging to the old continent, than of those belonging to the new.

That the Asiatic pole has materially diminished in power within the last one hundred and seventy years, will not admit of a doubt: inasmuch, as the European virtual line of no variation has, in that space of time, travelled east no less than 45 degrees of longitude; while the American true line of no variation, as far south as lat. 42° 30′ north, has retrograded easterly only about four degrees, as indicated by the difference of variation at Boston; and we have before shown, that the change of its position toward the east, or its increase of intensity, has not been commensurate with the shifting of the European virtual line of no variation. A strong proof, this, of the greater constancy of the American pole, both as to power and position.

We have not the least hesitation in saying, that all the apparent anomalies of the changes of climate, whether for a series of years or only for a season, may be explained by the motions of the cold pole as affecting the general terrestrial flows, when taken in conjunction with a necessary change of local circumstances, produced primarily by the movements of the cold pole itself. We can see a vast number of meteorological phenomena, which the change of identity of the absolute caloric of our atmosphere may produce in that atmosphere; but this is not the proper place for discussing them: in the Appendix, we shall insert a few in outline.

Inasmuch, as the passage of caloric, produced by the difference of polar and equatorial temperature, and by the demand of evaporation, is what causes the dip and direction of a magnetic needle or the phenomena of magnetism, it follows, that the mean of the annual variation of the dip of the needle, at any given place, will be the mean annual temperature of that place, taking that of the magnetic pole or magnetic equator as the standard of comparison. The greater the dip, the lower the mean annual range of temperature, and *vice versa:* though we must confess we are rather diffident in offering this rule.

We shall, however, endeavor to prove our position.

While the westerly variation has been constantly increasing, and with it, the amelioration of the climate of England, (situated on a meridian 95° from the meridian of either pole), the dip has been as constantly decreasing. Now, as caloric is the agent by which we suppose magnetism to be accomplished, and as the climate of England is milder, (by reason of the diminished intensity of the Asiatic pole), causing a smaller demand upon the existing volume of atmospheric caloric there, and as the soil partakes of the genial effect, it follows, that the moisture diffused through it will, being of a higher temperature, require the transmission of less atmospheric caloric to convert it into vapor. This, then, leaves a larger surplus to travel horizontally toward the American pole, (England being now west of the virtual line of no variation, obeys that pole), and thus diminishing the vertical force and increasing the horizontal, with every amelioration of climate, the dipping needle measures a smaller angle than formerly; and will continue to do so, if the Asiatic pole continues to diminish in intensity, or to retreat easterly.

A very singular fact, connecting the state of the dip with the state of the atmospheric temperature, is afforded by the before cited deflection of the line of 70° of dip, in the neighborhood of the northernmost range of that grand marine current, the Gulf Stream.

We now come to a prophecy which half a century may see fulfilled: it may even, by possibility, occur in our own time.

Previous to the great change which the year 1406 made in the climate of Europe, the grape was grown in England for the purpose of making wine, as in the south of France at the present day. One of the ancient vineyards is still in existence at Arundel Castle, belonging to the Earl of Surrey. For the last 300 or 400 years, however, it has hardly ripened its scanty crop upon walls exposed to the noon-day sun. We cannot attribute this to any defect in the plant itself, and change of climate alone will account for it.

It is not too much to assume, that the variation in England, antecedent to that period, was westerly: for, as the communication with Greenland was always open from about A. D. 804 till that year, the arctic ocean could not have been clogged up with ice, as the Greenland seas were clear, wherefore, the continental surface of Arctic Asia was then at its minimum, and during this period the vine flourished in perfection. In the year 1406, however, the accumulation of ice in the Greenland seas caused an accumulation also along the northern shores of the continent, and, increasing the intensity of the Asiatic pole, caused the virtual line of no variation, or balance of power of the Asiatic and American poles, to move gradually west over England to the meridian of the island of Ferro, as before mentioned. Here, then, was an alteration of climate; the vine refused to mature its fruit as formerly, and its cultivation was discontinued in consequence. But the ice at last broke up; for nature will not be forced, or allow extremes to prevail for any length of time, but so ordains it that every outrage upon her economy shall carry its antidote in itself. The virtual line then began to retreat easterly again, and passed over England the second time in 1657, since which time the variation has continued westerly: the Greenland ice has been gradually disappearing, and England enjoys a milder winter.

Should the westerly variation continue to increase, and the virtual line of no variation retreat much farther to the east, the rising generation will see Britain resume her ancient climate; and the vales of their forefathers, once more clad with the purple clusters of the vine, will echo back the vintage song, and the attendant sports of long-forgotten times will again rejoice the hearts of her peasantry, at an additional harvest after harvest-home.

As a further proof of the amelioration of the climate of England, we may mention that many North American plants, which would not thrive there formerly, such as the Azaleas, Kalmias, and the noble Tulip Tree, (Liriodendron), known in that continent as White Wood, and sometimes called American Poplar, with some species of Magnolia, are now found to succeed very well. Many Chinese and Japanese plants, also, are now supposed capable of being acclimated; such as the Primula Sinensis or Primrose Tree of China, and the elegant and beautiful Camelia Japonica. The Plane-tree or Button-Ball, in its stinted and uncertain growth, is a companion in misfortune with the vine. Formerly, this noble true grew around every dwelling, a favorite alike with the Roman and the Briton; for the last few centuries it has been a sickly plant lingering out a bare existence; yet now it seems to feel the renovating effects of a more genial climate.

Another lamentable instance of the deterioration of climate is found in the history of Iceland. When first discovered, and for centuries afterwards, it was a finely wooded country, supplying not only fuel, but timber for ship-building; but ever since the descent of the northern ice, this state of things has been gradually changed, and we wonder how it should ever have existed. Perhaps the period of a counterchange is not far distant.

In many parts of Scotland, also, which were formerly well wooded, and where the oak grew spontaneously, not an acorn will give promise of what posterity may hope for. It is also worthy of remark, that the lines of equal dip, coincident with the iso-thermal lines, or lines of similar mean climate, are also the boundaries of the animal and vegetable kingdoms, with respect to their diffusion over the world, in reference to latitude.

From the consideration we have bestowed upon the subject, we have no hesitation in affirming, that the dipping needle is a thermometer, or rather a climatometer, indicating every change of climate to which we are liable. For every increase or decrease of temperature will cause different horizontal and vertical forces, whose composition will affect it accordingly. We consider it capable of determining the mean annual temperature accurately: and consequently, other subjects connected with climatology, such as the annual amount of evaporation, &c., and as magnetic intensity varies in ascending above the surface of the earth, its oscillations may be applicable to the measuring of heights, and thus answer one of the purposes of the barometer.

If it shall be deemed that we have solved the real nature of magnetic attractions and repulsions; if we shall be deemed to have shown that they are no abstract qualities inherent in matter, but the result of impulses communicated in this or that direction; if we shall be deemed to have stripped these curious phenomena of the inscrutable mystery which seemed to envelope them; we shall now boldly and fearlessly discard the notion of attraction in any case. In fact, our reflections on this intricate subject of magnetism have almost induced us to discard the term *attraction* altogether, and substitute the word *impulsion*, signifying the act of being impelled or moved toward another body.

We confess we cannot conceive what attraction is. We cannot conceive an abstract quality appertaining to two or more particles of inert unorganized matter, without the sense of sight or perception of any kind, (for this supposes organization), by which they shall be so much more intelligent than intelligent beings, as to be susceptible of each other's presence in the immensity of space; and taking the shortest course to meet each other, show all the formality of kingly punctilio, and keep up the dignity of their persons by moving distances in inverse ratio with their bulks. It is irreconcilable with the nature of matter as matter merely, and is only explaining motion by itself. We conceive that all the heavenly and terrestrial movements may be referred to the diffusion of caloric. We hope we shall be deemed to have proved in the Appendix that the diurnal rotation of the earth is so; and we scruple not to say, that we can explain in what this diffusive tendency consists.

If we deny attraction as a quality of matter, we also deny that repulsion is; yet we would retain the term, understanding it to signify simply the act of being repelled or moved from any body, not as an inherent quality of matter.

To conclude: All the operations of nature are conducted on an extensive scale; and this is the reason that apparently weak and insignificant agents affect her purposes in the surest manner. In short, paradoxical as it may appear, her most yielding and imperceptible ministers are the most irresistible.

A mountain top may fall and bury the village at its foot: and here end the consequences, just at the spot where it fell. A torrent might have swept from the same mountain, and destroyed the same village; but it would have continued its course, and overwhelmed others in its way: its effects are confined to a line. The gentle breath of air which these villagers enjoyed in the morning, might ere noon, have blown a hurricane, and destroyed them in an instant, spreading destruction for leagues around: yet even the range of the hurricane is limited. But the most obdurate and immovable of nature's works, which will withstand the torrent and the storm, must yield to the slow but certain effects of that subtle and all-pervading element, caloric. The hardest granite rock that ever reared its naked points to heaven, and defied the storms of centuries and the lightning's blast, must yield and crumble into mould, when that very lightning, as if in vengeance for the insult offered to its slighted power, shall lay aside its visible form, and sap its nature under the semblance of soft friendship, in the gentle form of calorific warmth.

The most trifling alternations of heat and cold will do wonders in the economy of nature: and the miraculous creative powers of the slightest variations in the quantities of caloric, in some cases, are only equalled by the destruction occasioned in others. That same agent, which bids the acorn vegetate and spring up into the towering oak, rears it to its prime; then insidiously saps the fountain of its vigor, and destroying the cohesive attraction which itself created, renders it once more to the earth from whence it came.

Caloric is the agent which causes all the revolutions which take place in terrestrial matter. It is God's vicegerent upon earth, omnipotent and omnipresent: and shall we doubt that that power, which, under its Creator, performs confessedly such stupendous wonders, can direct the needle in its course?

It is, in fact, the very magnitude of the scale on which it acts that makes its effects perceptible. Were the solid crust of the earth infinitely smaller than it is, with an atmosphere extending to its present limits, the poles would be of the same temperature as the equator, and calorific directive influence, or magnetism, would cease.

There is something grand in the thought, that man should possess an instrument, that will, if he reasons rightly on its affections, tell him what secret machinations nature is conducting in those distant and inhospitable countries where no human foot has trod; and where the thoughts of his fellow men have never before reached, unless, indeed, it be the inquiring spirit of the philosopher over his midnight oil.

There is something lofty and spirit-stirring in the thought, that man may cast his eye south upon a balanced needle, and be able to revolve in his mind the vast changes which are perpetually going on, thousands of miles north of him, in those ice-locked regions where none but the bear and the fox can see what nature does.

There is something noble and sublime in the thought, that man, frail man, should be able to revolve in his mind the past, the present, and the future, respecting the condition of those remote spots of this earth which his Creator has hidden, as it were, from his view, and pronounced uninhabitable by him.

And if the power of diving into the abyss of past and future time; if such wisdom as this belong to created man, by reasoning on effects which he produced not, how shall he dare to question the omnipotence and omniscience of that Being who created both him and all things out of nothing?

APPENDIX.

In the course of our previous reasonings, the solutions of many phenomena, some intimately connected with the subject, and some isolated, presented themselves to our notice, which could not with propriety be introduced into the body of the work, as they would only have distracted the attention and have broken several links in the chain of argument. Considering some of them, however, as not unimportant, we reserved them for insertion in an appendix.

The diurnal rotation of the earth, producing the alternations of day and night, and causing the diurnal variation of the needle, is a phenomenon of the utmost importance to solve; and it is with great diffidence that we venture to lay our opinions on the subject before the world.

If we conceive the earth, (or any other planet), as a sphere, and of uniform substance and temperature when first created, and before it was exposed to the influence of the sun, it is plain that its centre of gravity coincided with the centre of magnitude. But this coincidence would be destroyed, as soon as the solar influence was exerted, by the simple action of caloric, and the inevitable consequence would be a rotation, the nature of which we shall explain.

As the earth is of a globular form, one half of it only is exposed to the sun's rays, and therefore, only one half accumulates caloric, at a time. Now, one of the effects of caloric is to increase the volume of matter without altering its gravity, (because all our operations for ascertaining the weights of bodies, are necessarily conducted in an atmosphere of caloric); therefore, the hemisphere exposed to the sun becomes elliptical, (accounting for the earth's oblate spheroidal form), with its greater axis coincident with that of the cone of reception, and specifically lighter, bulk for bulk, than the other hemisphere. It is now evident, that the centre of magnitude is in advance of that of gravity, and as the tendency is toward the sun, (no matter why), the whole globe turns to bring the centre of gravity in advance of that of magnitude; for a body cannot fall with its light end foremost. As the earth turns from west to east, the heated eastern meridians pass successively into the sphere of action of the cone of transmission, radiate their heat, and contract to their original form just before sun-rise; while at the same time, the western radiating meridians become the eastern meridians toward the cone of reception, (or the meridians of sun-rise), collect the solar beams, as they advance toward sun-set, and, expanding the volume of their bulk, bring the centre of magnitude in advance of that of gravity.

Thus, there is a perpetual effort of the centre of gravity to precede that of magnitude, which yet can never be accomplished; for as the contracted meridians expand, and the expanded meridians contract, simultaneously, the centre of magnitude must always be in advance of that of gravity, and a perpetual revolution is the consequence, producing the phenomena of day and night.

The inclination of the earth's axis of rotation may be conceived to be owing to the actual disposition of land and water, and its situation with respect to the sun, when first exposed to the action of that luminary. Its first movement took a westerly direction, which has continued ever since, most probably by the coincidence of the meridian of 170° or 180° E., (passing through the vast Pacific ocean), with the celestial meridian, when first exposed to the solar influence. We mean a meridian, situated east of the then greater mass of land; for we do not presume to suppose that the continents were the same then as now. Water expanding, with equal increments of heat, in a greater ratio than land, this would cause the centre of magnitude to advance from the centre of gravity in the plane of that meridian, when the Asiatic continent to the west would turn east, (being the largest mass), as an effort to bring the centre of gravity in advance of that of magnitude. When once in rotation, it must continue to revolve, and with the same velocity from day to day, while the same quantity of caloric continues to be delivered; for successive meridians heat and cool by the same self-acting cause; a perpetual motion and a lasting monument of the wisdom of its Creator. This might be considered as the first meridian.

Although the velocity of any meridian, from day tc day, may be considered uniform, it may nevertheless vary from hour to hour; for the aqueous meridians being expanded by the solar heat more than the terraqueous, they will pass the celestial meridian with different velocities, and thus cause the celestial hours to vary in length.

The diminishing obliquity of the ecliptic and the nutation of the earth's axis may be occasioned simply by the inclination of the latter to the plane of its orbit; by reason of which the northern and southern hemispheres are alternately exposed to an increased and decreased solar influence. During the northern summer, the greatest expansion of the meridians, (and consequently the greatest radius), is north of the equator; wherefore, the centre of magnitude is removed north of it also: so that the effort to bring the centre of gravity in advance of that of magnitude, is not constantly exerted in the plane of the equator, as at the equinoxes, but in a spiral, every point in which forms a northerly angle with it, corresponding with the place of the sun in the ecliptic. The reverse takes place in the southern summer. The consequence is inevitably fatal to the parellelism of the earth's axis of rotation, resulting in a tendency to bring it perpendicular with the plane of its orbit; and at the same time causes the diminishing obliquity of the ecliptic, which will finally end in its coincidence with the equator.

This supposes the earth's axis of rotation permanent with respect to its own mass: but the probability is that this alternate action would shift the axis itself, and consequently the poles or terrestrial north and south points, altering of course the terrestrial equator also, and with them the position of the magnetic equator and magnetic poles.

We were startled at the consequences which would result were this the case, and had determined to omit such a bold inference; but we were confirmed in our theoretical conclusions, by reading sometime after a suggestion, whether the *geographic meridians* might not vary in time. So far back as 1780, it was observed that the old meridian line of the church of St. Petronio, at Bologna, varied no less than *eight degrees* from the true meridian line of that time. Some may attribute this, (though we think it impossible), to the volcanic agency which has affected the soil of Italy from time immemorial: but the following observed instance will remove the doubt. The meridian line of Tycho, at Uraniburg, has varied *eighteen minutes* since the time of that philosopher. Every one will allow that he could lay a meridian line correctly, and that this is not a volcanic section of country. This would, in the course of time, prove a fertile source of magnetic variation.

There is an awful grandeur in contemplating these vast but silent changes, and thus looking forward to the probable issues at present concealed in the womb of time, and casting back the mind's eye in retrospect, to ages long antecedent to the existence of man, when we see the tropic fossils scattered through Siberia, may we not naturally inquire, "Did not the equator once pass through this dreary and inhospitable region, and have not the four cardinal points of the compass suffered one reverse at least, since the creation? Nay, more:

may not the geological changes of the surface be silently causing another reverse at the present time?"

There is another effect which this heating and cooling of the meridians may produce, which, though not immediately connected with the subject, we cannot refrain from stating here in outline: we allude to the origin of the tides.

Their cause has been sought in the *attraction* of the sun and moon; but we are strongly inclined to doubt this, and refer their production to the effects of terrestrial expansion and contraction, caused by the alternate heating and cooling of the geographic meridians. For as water will find its level, and as this is continually disturbed by the action above mentioned, a tide, as an effort to restore it, is the inevitable consequence.

In intimate connection with climatology, is the phenomenon of the decrease of temperature with the increase of altitude. We think it may be easily explained.

If we assume two perpendiculars at any given distance apart, we know that they are not parallel but diverging lines, which meet at the centre of the earth; therefore, if we give a circular motion to a perpendicular, we generate an inverted cone, whose apex is at the centre of the earth. If, then, the same quantity of caloric exist in any two neighboring strata of air of equal thickness in this cone, their sensible thermometric temperatures will not be the same; for the upper stratum being wider than the lower, by reason of the diverging sides of the cone, and its density being less, because the superincumbent pressure is less, it follows, that the same quantity of caloric is diffused through a wider space, and the sensible thermometric temperature is proportionally diminished.

Thus, the caloric of boiling water, whose sensible thermometric temperature is 212°, and which scalds the hands, is harmless when its volume is expanded 1728 times with the water which contained it, although, in becoming vapor, it absorbed 1000° more of caloric.

Another view of the subject is this: if the sensible temperature of the upper stratum be known, it is evident that any under stratum will be warmer, because the quantity of caloric transmitted to it from above, converges in its passage to the earth, and the same effect is produced as by the artificial action of a lens.

This shows how wise Providence is, to have limited the extent of our atmosphere; for every increase would, *cæteris paribus*, give an increase of temperature at the surface. With an atmosphere extending very considerably beyond its present, limits the torrid zone would be utterly uninhabitable, and the polar regions have a tropical temperature. To this we may add, that the use of an atmosphere, in relation to the planet itself seems to be to collect the rays of solar caloric travelling from their source into space, and transmit them, to the solid nucleus for the purpose of nature's economy; and it shows us, that notwithstanding the different distances of the planets from the common fountain of their warmth, the temperatures of all *may* be the same, (we say not, that they are so), and consequently the constitution of their substance and inhabitants, in all the different grades of life and existence. Give them but an atmosphere, in proportion to their bulk, and distance, and their sensible temperatures, owing to the proportional quantity of caloric collected and converged to the globes themselves, may be regulated to any degree.

Thus, taking our earth as the standard, Mercury, which is so much smaller, and nearer the sun, may by a proportional decrease of the height of his atmosphere, and consequent diminution of the quantity of caloric collected and converged, have his temperature equalized with our own: while Jupiter, which is so much larger and farther off, may have his temperature equalized by a proportional increase of atmosphere, and of consequent calorific collection and convergence. We should recollect, that though the heat of the sun *decreases* upon any given surface inversely, as the squares of the distances, by reason of the divergence of his rays; yet, on entering an atmosphere, his rays *increase* in intensity, in the same ratio, by reason of their convergence.

With reference to the rainy seasons of tropical countries, the devious and irregular direction of the magnetic equator will have a material influence in their production. For they will be determined by the passage of the sun over the magnetic equator, and not by its passage over the terrestrial. As one portion of the magnetic equator passes north of the terrestrial equator, and another south, it is evident that the phenomena exhibited on the Asiatic continent, at the two periods when the sun crosses the magnetic equator, during the northern summer, will differ very considerably, perhaps, from the phenomena exhibited on the North American continent at the same period; and so, also, at the two periods when the sun crosses that part of the magnetic equator south of the line, during the southern summer, the phenomena exhibited on the South American continent will differ materially from those exhibited in southern Africa and New Holland.

It seems extremely probable to us, that the theory of the change of calorific identity which we have taken notice of, will be found capable of solving a vast number of phenomena which have seemed hitherto shrouded in a veil of mystery.

May not the approach of bodies, floating in a liquid, be traced to this principle? It would be a curious inquiry, whether there is any particular position that they assume with respect to each other's forms and specific heats, and to the general equatorial flow. Perhaps all other attractions and repulsions may be traced to the same origin; even capillary attraction.

Nay more: we think it will abundantly account for molecular and atomic cohesion, for we have but to consider each molecule a magnet as respects its fellows, and the problem is solved.

We will proceed one step more in the extension of the principle, and inquire, "Will not the change of identity in the absolute caloric of bodies, or some other curious modification of calorific action, account for even the production of that mysterious phenomenon, 'Gravitation ?'"

Doubtless many of our bodily sensations may be referred to the same causes, and thus the theory may be beneficial in a medicinal point of view. We shall give an instance.

It is well known, that there are two periods of the year, spring and autumn, when the habitudes of the body undergo a remarkable change. Now, in winter, when the temperature of our bodies, (if healthy), is much the same as in summer, magnetic intensity is at its weakest, that is, the change of identity of our actual volume of caloric is at its minimum. When, therefore, we are accustomed to the hybernal rate of change of identity, we are in a peculiar state of body suited to that rate. At the return of spring, however, with the northern progress of the sun, the rate of change is increased, and we have to adapt, or rather the then rate of change adapts, our body to the circumstance. It is to this change of state that we must refer our spring sensations. When summer, and, consequently, magnetic intensity is at its height, the rate of change is at its height, and we are accommodated to it. It remains thus in a sort of stagnation sometime previous and subsequent to the return of the sun to the equator; after which the rate of change diminishes, when the state of the system must undergo another modification, and we experience unpleasant sensations with the progress of autumn. The one is caused by an increasing, and the other by a decreasing rapidity of the change of calorific identity.

There are four facts, independent of the effects which we have noticed it to have on the magnetic needle, from which we conclude that caloric is really a material agent. They are: 1st, That the hottest period of the day is not coincident with the meridian. 2d, That the hottest period of the year, in the middle latitudes, is not coincident with the summer solstice. 3d, That the middle latitudes often indicate a greater range of thermometric temperature than the tropical at the same time: and 4th, That a thermometer placed at certain distances above the soil, stands higher than when placed nearer the soil.

As explaining the first we would remark, that if motion were the cause of heat, then the communication of it would be the most intense at the meridian, because it is then delivered nearest the perpendicular, and we cannot conceive a concentration of motion after the motive cause, (the sun), is removed, that is, approaching toward sun-set. Motion, as the cause of heat, will explain the increase and decrease of temperature with the approach of meridian and sun-set, but it will not explain why the greatest accumulation of caloric takes place after the meridian. Now, a material agent will explain it. For when the sun is perpendicular, (we assume a place where the sun is vertical), say on longitude 90° W., the caloric he delivers forces the existing quantity in all directions, north, south, east, and west, and among other places from long. 90° along the parallel of lat. to long. 92° W. Now, as the sun moves west, and becomes vertical at long. 92°, the displacing of the existing body is, for one point of the compass, from long. 92° *easterly* to long. 90°, causing a temporary pressure against the current of caloric, already in motion, from thence to the west; and, consequently, a stagnation and accumulation ensues; when the sensible temperature rises of course, that is, the thermometer indicates the presence of a larger specific volume of atmospheric caloric. The meeting of two motions, on the contrary, would only cause a diminution of the stronger, in the ratio of the intensity of the weaker, which is absolutely destroyed; that is, a diminished sensible temperature; and if the two forces were equal, they would neutralize each other, and produce absolute cold, or the calorific zero.

The second case, also, is inexplicable on the motive theory. When the sun is on the northern tropic, it is at its greatest proximity to the middle latitudes, and consequently, on that theory, it should have the greatest power there. As after that day it retires south, that is, the vibratory motions it occasions are becoming weaker in the middle latitudes as they recede from its influence, and as the vibrations of the solstice are already in transitu to the pole, and their intensity decreasing with the increase of density in the medium of transmission; therefore, the sensible temperature would decrease from this time, if motion were the cause of heat. If we consider caloric as matter, this phenomenon is easily accounted for. The velocity of the equatorial current is very great at the equator, and decreases from thence to the pole by reason of the increasing density of the medium of transmission; and this check of the current causes a stagnation in the middle latitudes; and the delivery, though diminished, still continuing when the sun is returning south, causes a further augmentation to the stagnant volume of caloric in the middle latitudes; that is, a higher sensible temperature after the solstice. When, however, the nights of the frigid zone begin to lengthen, and their specific volume of caloric to diminish, then the stagnant volume travels northward, and the temperature of the middle latitudes becomes lower.

The same objections apply with equal force to the third phenomenon on the motive theory, but are agreeable to the material. For we have shown in our lemmas and theorems that the incoming supply, when vertical, causes an equality of temperature by displacing a volume equal to itself; and we have also shown that an accumulation takes place in the middle latitudes by the increasing density of the medium of transmission; for both which reasons, the sensible temperature should be higher at times in the middle latitudes than in the tropics. To which we may add, that the proportion of land to water is greater in the former case than in the latter.

With reference to the fourth phenomenon, if motion be supposed the cause of heat, it could not be produced. For, when it had reached the earth, caloric could not rebound against a force equal to itself without causing an absolute calorific zero at some short distance above the surface; for motion proceeding direct against motion will destroy each other. But, as the capacity of the atmosphere for caloric is infinite, the consequence is that the resiliance of the element against the influx will inevitably cause an increase of the specific volume of caloric at some distance above the surface; producing the fourth phenomenon we have mentioned.

On these four grounds, then, we think we have proved that warmth is not caused by a vibratory motion of the particles of matter, but by a material agent.

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